Evidence in Images

Investigating Photos of Mars

by
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Part 1: What's Wrong With the Rainbow on Mars?

Before I was 7 years old, I could recite the list of planets in the solar system. I loved all things astronomical. I couldn't get enough. When the Viking probes landed on Mars, it was one of the first major events I can remember. When the January 1977 issue of National Geographic came through the mail slot, I devoured the article about the mission to Mars and all the glorious colored photos. I remember quite distinctly observing that the sky was blue in the images. Mars, the red planet, had a sky similar to our home world.

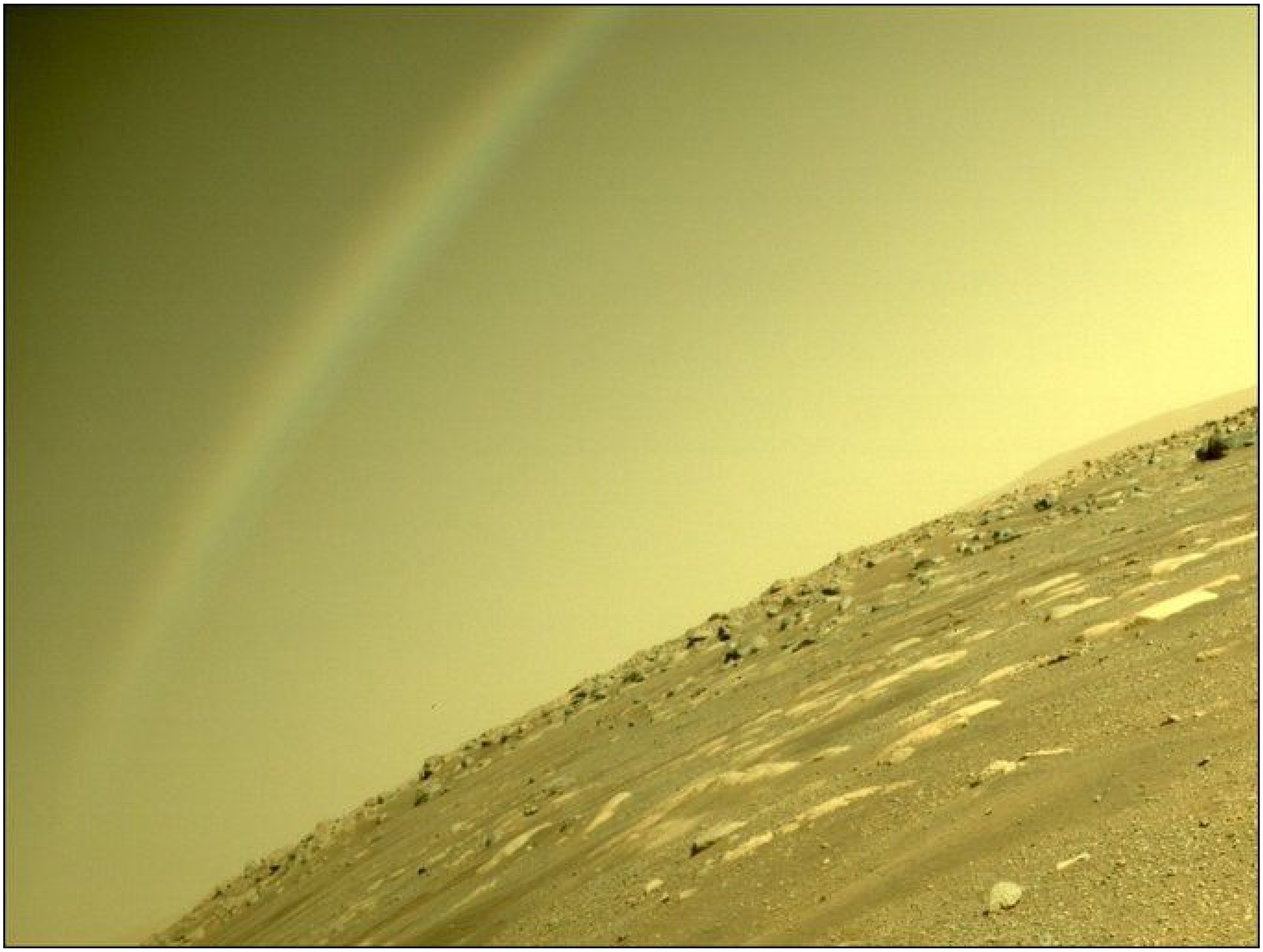
However, over the years as the next probes were launched to Mars, I noticed that the images coming back and being released no longer had any blue skies. Everything was a drab orangey-red. Things were very indistinct, almost washed out looking. The explanation given was that the atmosphere of Mars was constantly filled with dust storms and the particulate matter was a persistent condition. This was apparently confirmed by images of the probes themselves which clearly showed they had color swatches so that any images could be examined and color corrected. Those experts at NASA must know what they are doing.

If you've done any research into this topic, you've probably come across various websites which state all sorts of ideas - from the idea that images from Mars are actually from a desolate Canadian area to the theory that the physics of light behave differently on Mars. I won't assign any intent or agenda for any agency. My goal is to examine various images and ask a very simple question.

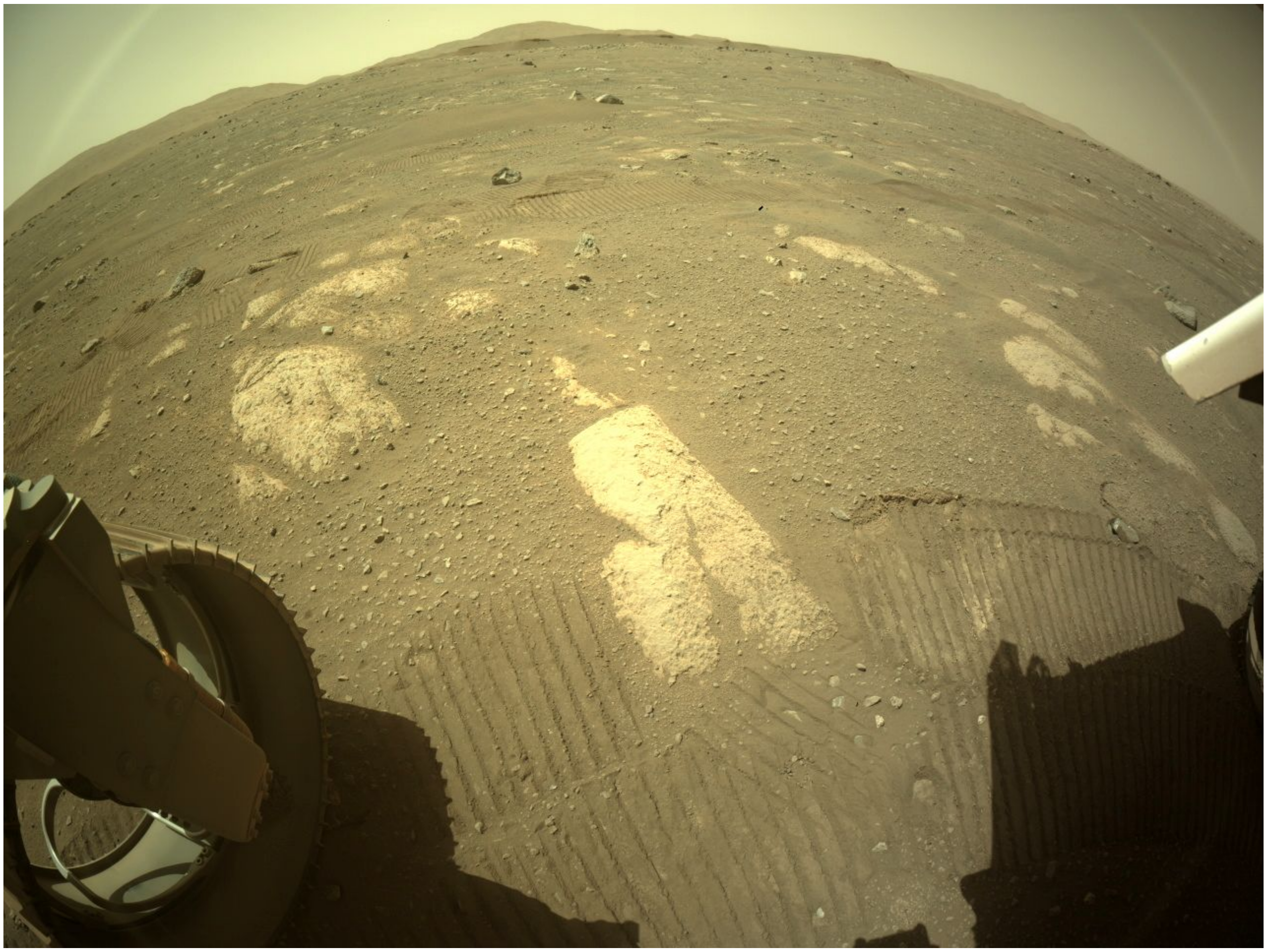
I'm asking the following question which will guide our discovery and promote our curiosity: how can the data contained in the images prove or disprove what our eyes are seeing in the images?

Note: Please click on the image to open full size resolution.

Is That Really a Rainbow on Mars



This whole topic came to my interest again just recently. There was an image that was widely shared which supposedly showed a rainbow on Mars. People were thrilled and amazed. NASA quickly debunked the notion but still people held on to this belief. Let's use this as the start of our discovery. Here is the image that was shared and it does seem to show a rainbow stretching to the horizon. The image is very yellow. That's the first observation that something about the image is not quite right.



As with any research, we have to determine the source of the image. We find that the image is actually cropped from the top left corner of the original image. There were several images in the series taken that day so the image shown here is another in the series. They all have "rainbows" at the same spot. And there is a "rainbow" in the top right hand corner of the images too - a mirror image. This shows that there is no rainbow but it is a camera lens flare due to the way the light is entering the camera. A rainbow on Mars has been debunked.

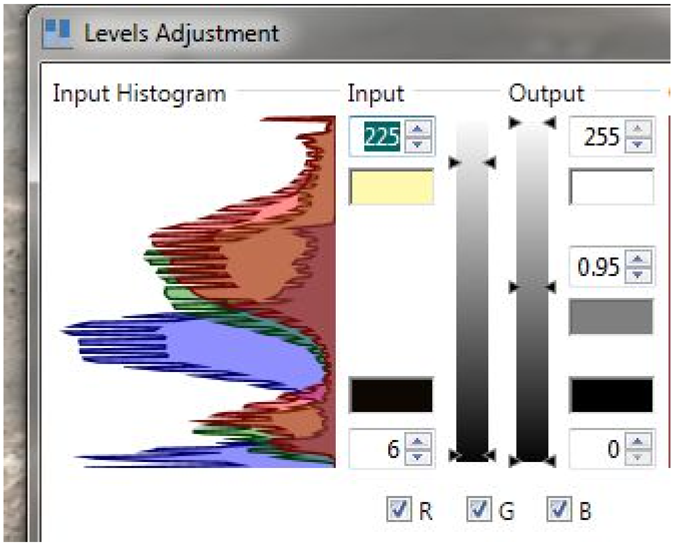
However, have you noticed something that is a bit off with the images? The first image has a noticeably more yellow tint than the second image. Now it could be that the image that was cropped and shared on social media was purposely color modified. But the second image is taken from an official NASA source and is an official release. It too displays a yellowish tint. This is especially noticeable on the rover's painted metal on the right side of the image. It should be pristine white but in the image it is very much yellow. We've come to accept the answer given by the experts that the atmosphere on Mars is constantly filled with dust which gives everything an orange, yellow or red tint depending on the conditions. And this image is no different. Yes, but this image has a lens flare.

Did you ever play with a prism when you were younger? I did. Again, this fascinated me. It was amazing to me that rainbows were hidden within sunlight. I ran around the house trying to overlay the rainbow light on different textured surfaces to see what they looked like. But then a cloud moved over the sun and the diffracted light disappeared. I would have to wait until the cloud moved away and the rays of the sun again returned to hit the prism for the rainbow to appear. On a foggy day there was no chance for me to play with the prism since there was no sunlight at all.

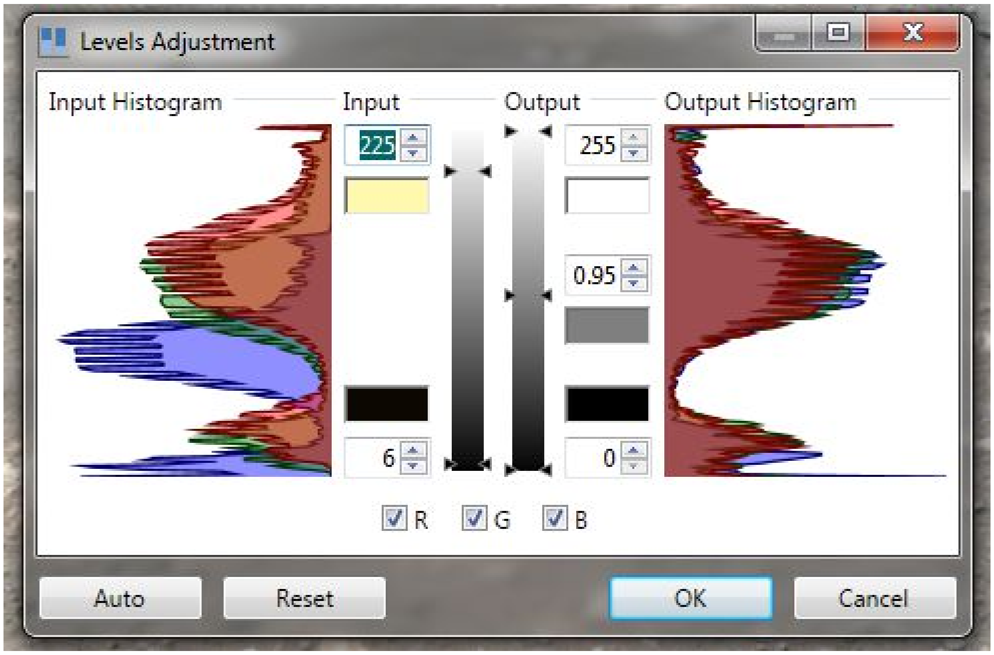
Hey, what a minute. We are told that on Mars, the sky is always filled with dust particles - just like fog. So how can there be a lens flare happening in the rover's camera if there are no rays of sunlight getting through the atmosphere? A lens flare which is a diffracted light beam would be impossible if there was dust in the air. And besides, the image showing the lens flare doesn't display the true hues of light from a prism. They are tinted the same yellow as the rest of the image. The diffracted light in the camera lens would not be affected by the dust in the atmosphere - it wouldn't take on a yellowish tint - it would be a true color "rainbow". So there is something very wrong with those images.

This means that we can determine the following: the existence of a lens flare means that the sky must be clear to let unrestricted rays of light through and the color of the image must be wrong since the "rainbow" is not made up of true colored hues.

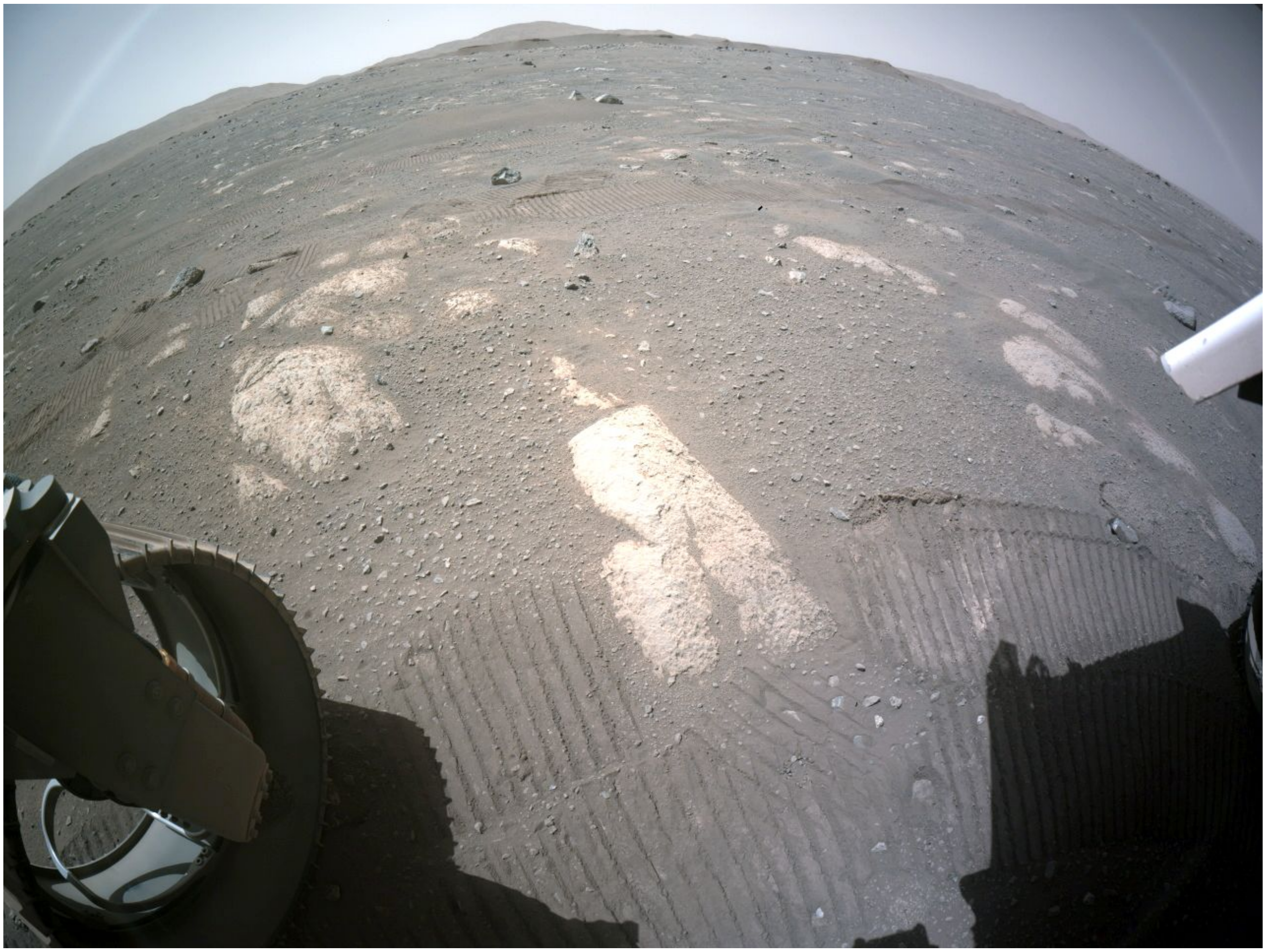
Let's see what kind of image manipulation can be done to hopefully correct for these observations. Anyone can load these images into a computer paint program and do this themselves. I'm using paint.net



Using the "Levels Adjustment", overall or each individual RGB color channel can be modified. Press the "Auto" button for the software's best guess at the proper levels. This is usually an acceptable result. But by manually considering what is happening, we can gain greater insight into the issue. The image to the right displays the color levels of the default image. Each color channel has its own curve which shows how much of the light/dark range occurs in the image. Do you notice anything about the levels? Each channel has two major spikes along its curve. Currently they are not synchronized.



Thinking about an image, it would make sense that the light/dark areas of all colors would match in the same spot. Each channel can be modified individually so that they occur together. On the right hand side you can see that this was done and the curves now match much more closely. How does this affect the image?



It makes a huge difference. First, the lens flare is now displayed in accurate color hues matching a "rainbow". Second, the rover's white paint is a more true white. And third, the sky of Mars is blue. Is this a more accurate depiction of the environment on Mars? I would say that according to the physics that are being displayed in the image, yes.

Part 2: Examining Images From Mars

In Part 1, I investigated the now debunked "rainbow" in images from Mars. While the evidence showed that the displayed "rainbow" was not due to water vapor in the atmosphere but was a lens flare in the rover's camera, I don't think NASA is aware that their answer raises more problems. The very existence of a diffracted light ray (lens flare) means that there is unobstructed atmosphere in the view range of the camera. The officially released image shows a definite yellowish tint over the entire image which experts explain is due to persistent particulate matter in the atmosphere due to massive dust storms. Taking that explanation at face value it would be impossible for an unobstructed light ray to reach the camera and diffract into a lens flare. To state things more clearly, if there truly was that much dust in the atmosphere, all incoming light rays from the sun would be scattered. In addition, the image shows that the hues of the "rainbow" diffraction are very much tinted yellow - almost as if they were being affected by the dust as well. If it is a lens flare, the diffraction is happening inside the camera away from any dust and would be displayed in pure hues. All this suggests that the image is a false color image.

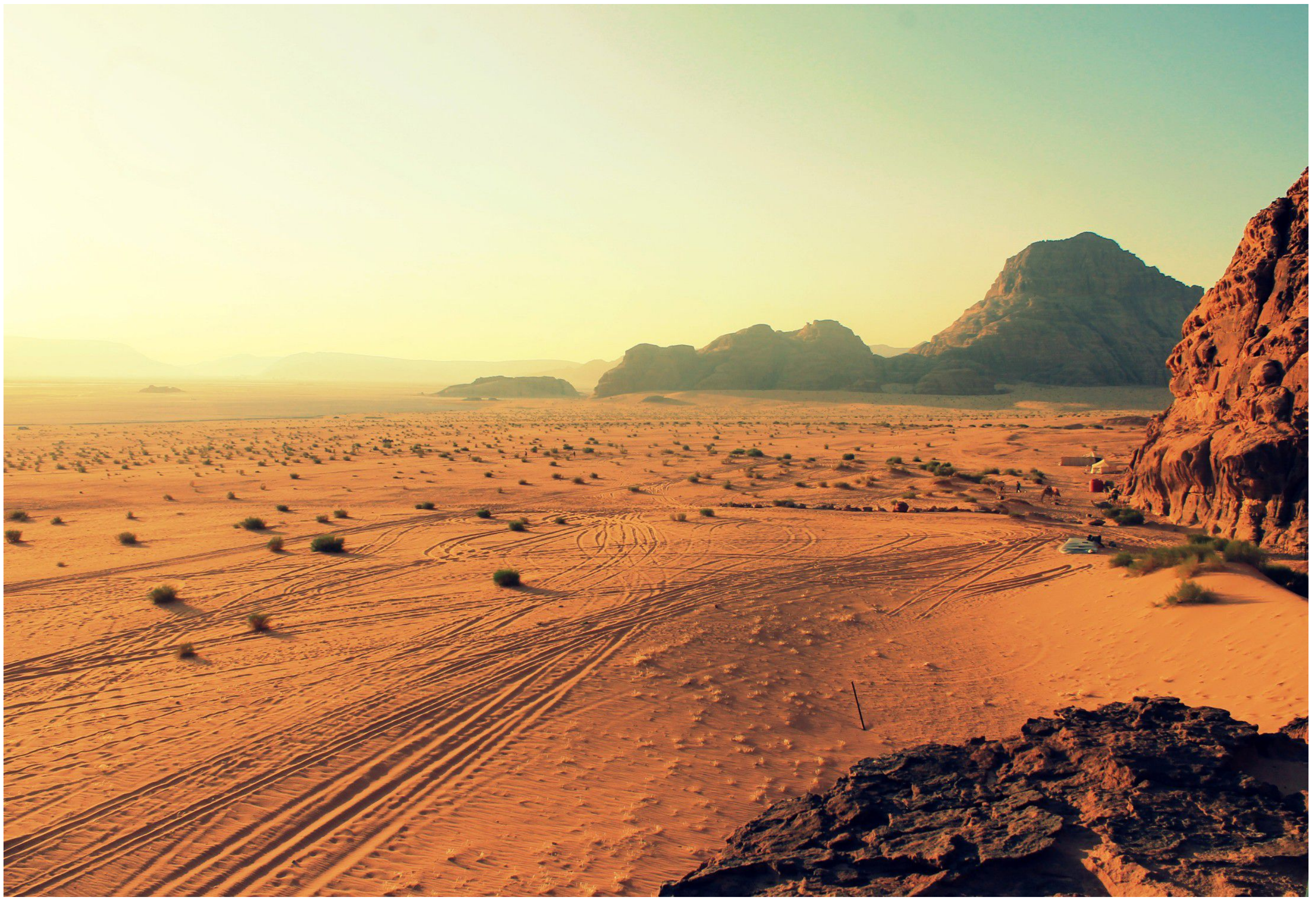
I then showed how it is possible to manipulate the image in any image software and modify the color level channels. The image had 2 major spikes along each color channel curve. When the curves were synchronized, the resulting image no longer had a yellow tint, whites were displayed accurately, the rainbow diffraction was displayed correctly and as a result, the sky was blue. This is a very interesting result and raises quite a few more questions. By proving that the "rainbow" lens flare is internal to the camera, the other issues that result are more serious and affect every other official image that has been released over the years.

Our curiosity has been piqued. We have to begin by stating that images from Mars can not be verified since there are no humans to validate the images. That seems obvious but needs to be said. What else can be examined in order to determine if these image manipulations could very well be leading to a more accurate image? Let's see if there are any images in our known environment which show similar issues. If we can compare these to what we know of physics, these can then be applied to the images from Mars.

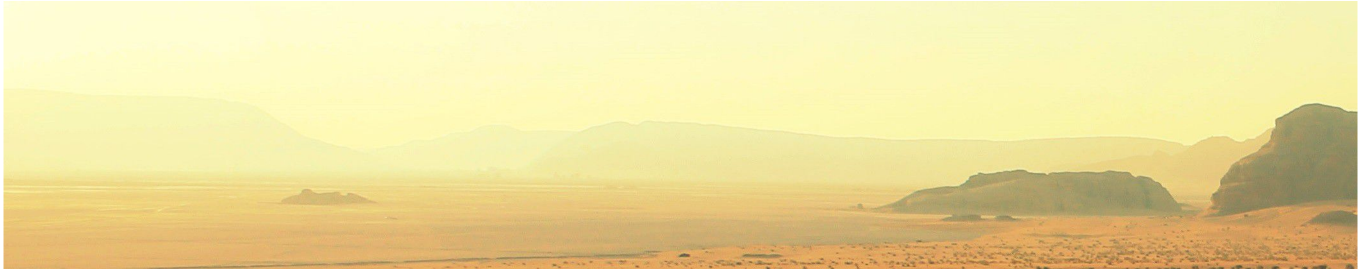
Note: Please click on the images to open higher resolution versions

Exhibit A

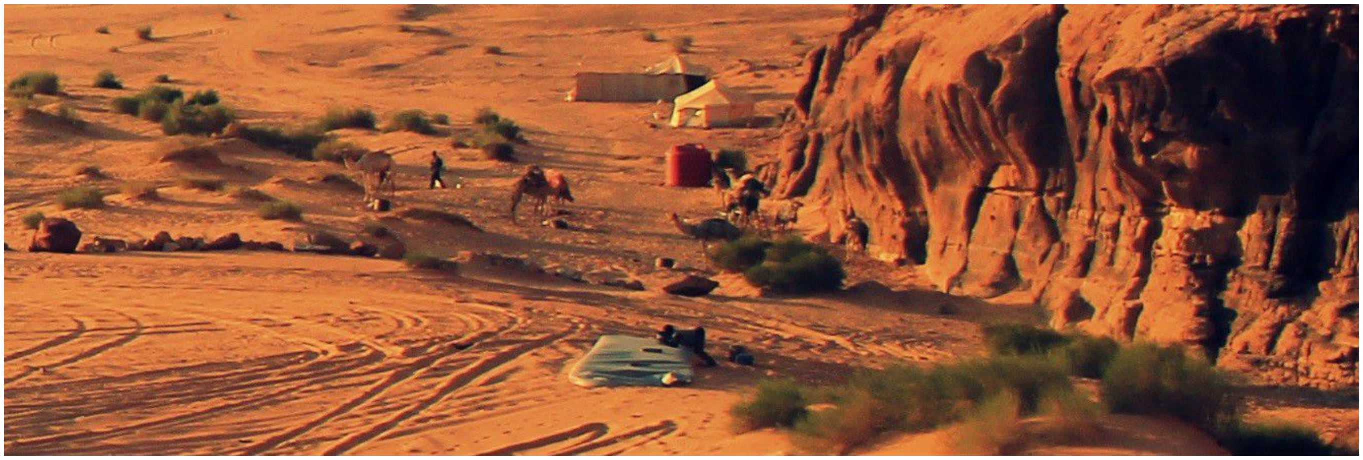
Let's examine this image to start. How is this image similar and different from images we've seen from Mars?

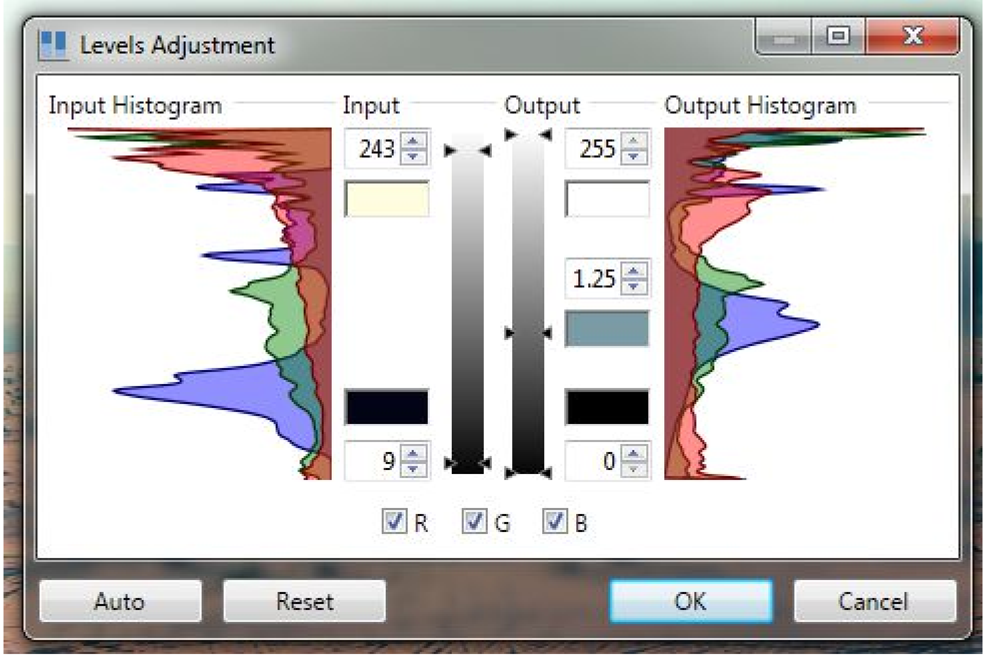


First, it's obviously a desert landscape and has an overall reddish hue. While the foreground is sharply in focus, there is noticeable atmospheric haze. This lessens the overall details the further one goes back towards the horizon. The far off hills take on the overall color of the atmospheric haze and the detail contrast is washed out.



The shadows of the shrubs are very long. This image looks like it was taken during "magic hour", just before the sun is setting. This gives the entire image an overall glow. We can see this by looking at the tent at the mid ground. It is a white material but has taken on a yellowish tint.





Input: 243

Input: 9

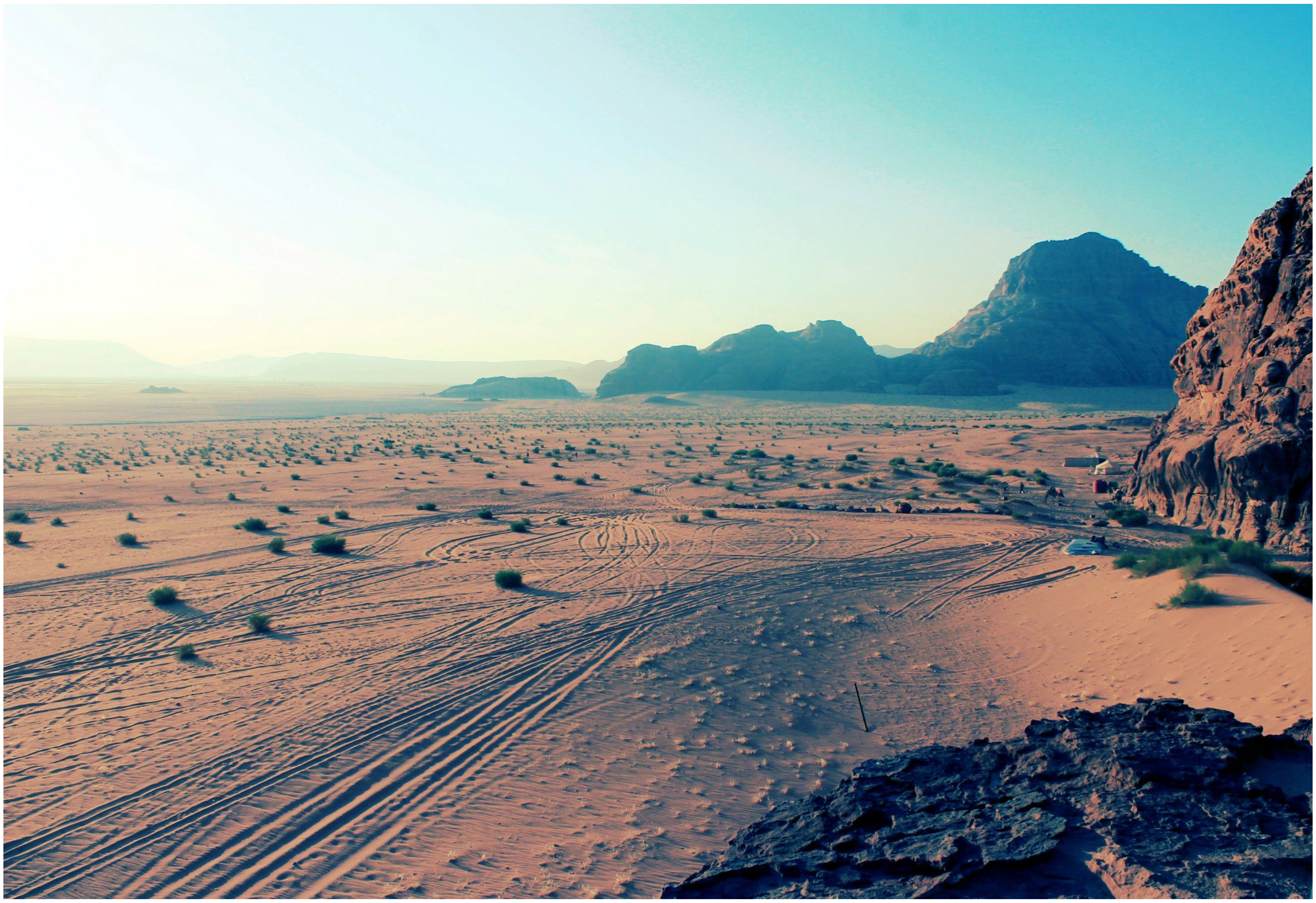
Output: 255

Output: 1.25

Output: 0

☑ R ☑ G ☑ B

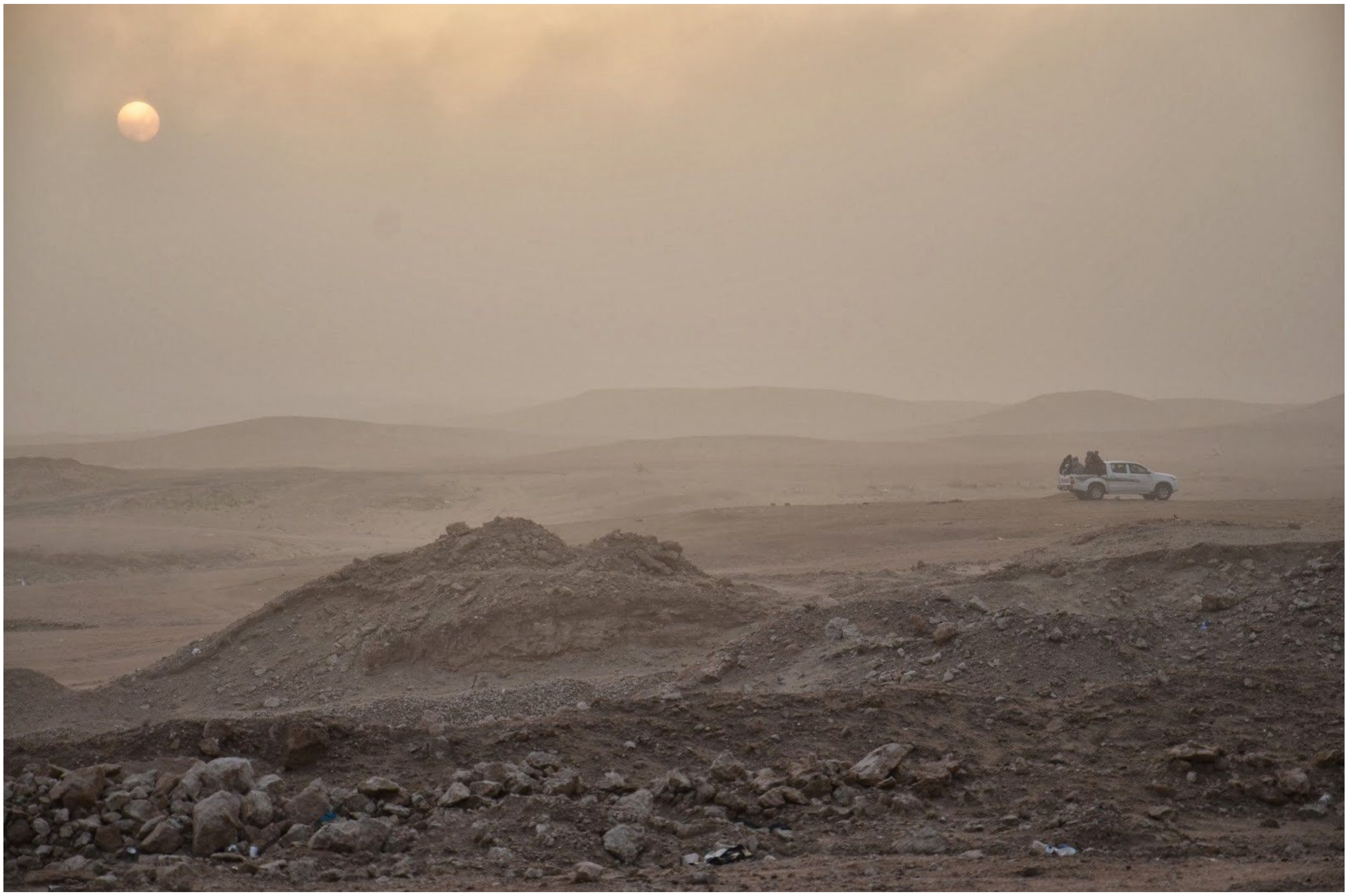
What do the color channel levels tell us? The levels on the left side are the original image. You can see each channel has spikes occurring at different points. On the right, the channels have been synchronized somewhat - they don't match exactly. But the intensity of light for each channel occurs roughly at the same place. How does this affect the image? The image is less over exposed and the image takes on a more "natural" look. Equalizing the color levels removes the specific lighting effect for the time of day being photographed. However, where the distant hills were washed out and contained no detail, there is still no detail visible due to the particulate matter in the air.

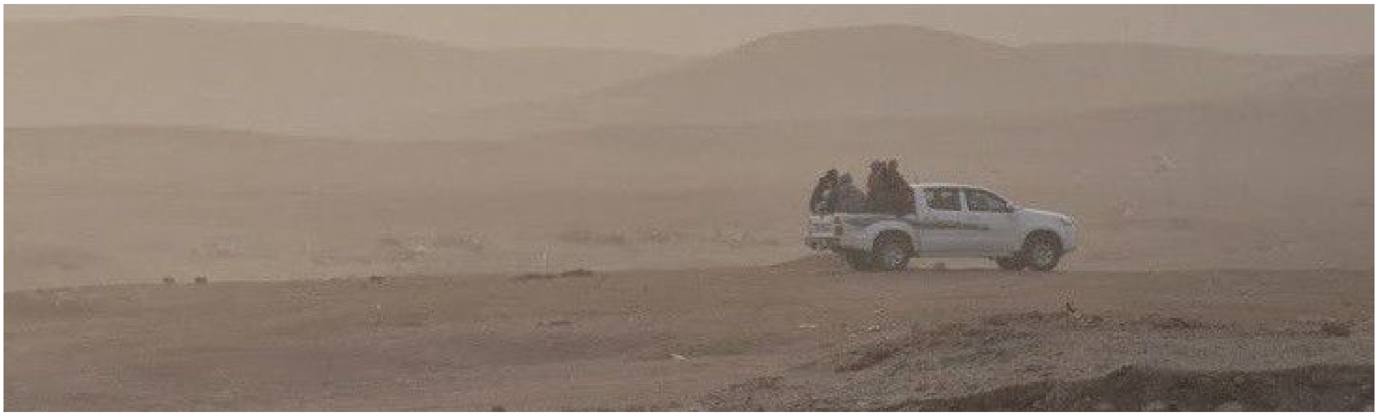


It would seem that light levels for each color channel should occur in roughly the same place for a normal clear sky in full sunlight.

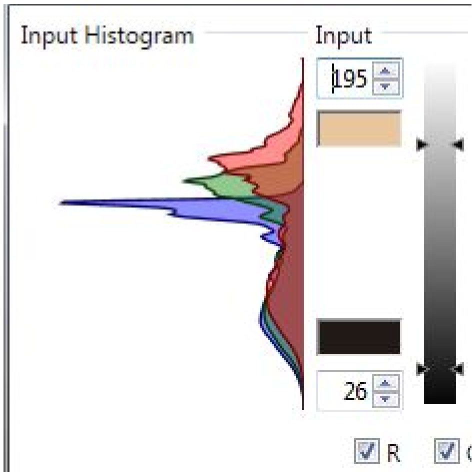
Exhibit B

Let's consider this next image. Here is another desert landscape with the sun obscured by fog. The camera is pointed directly at the sun and therefore the image has taken on a bright glow. Notice that even though the camera is pointed toward the sun and usually noticeable lens flares would result, none occur in this image. This shows that no light rays can directly make their way to the camera. They are all being scattered. The shadows are not dark but are very soft and diffuse.

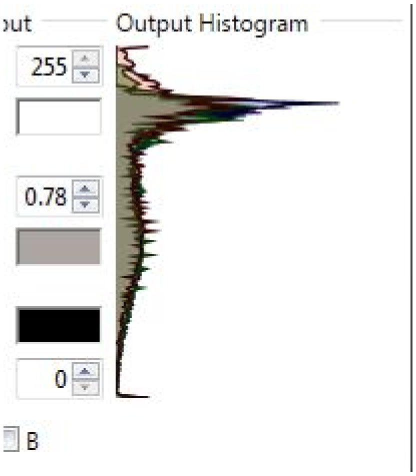




This glow is clearly seen by focusing on the white pickup truck. We can tell it is painted white but in the image it has an orange tint. In this image the fog is so dense that even the mid ground hills quickly lose detail and become more washed out the further into the horizon you look. Anything in the far distance can not be seen clearly.



What do the color level channels look like? Notice that the overall shape of the three channels is similar but they are offset.



If the channels are synchronized so that they better match, then there are significant changes to how the image looks. The effect of pointing toward the sun is removed.

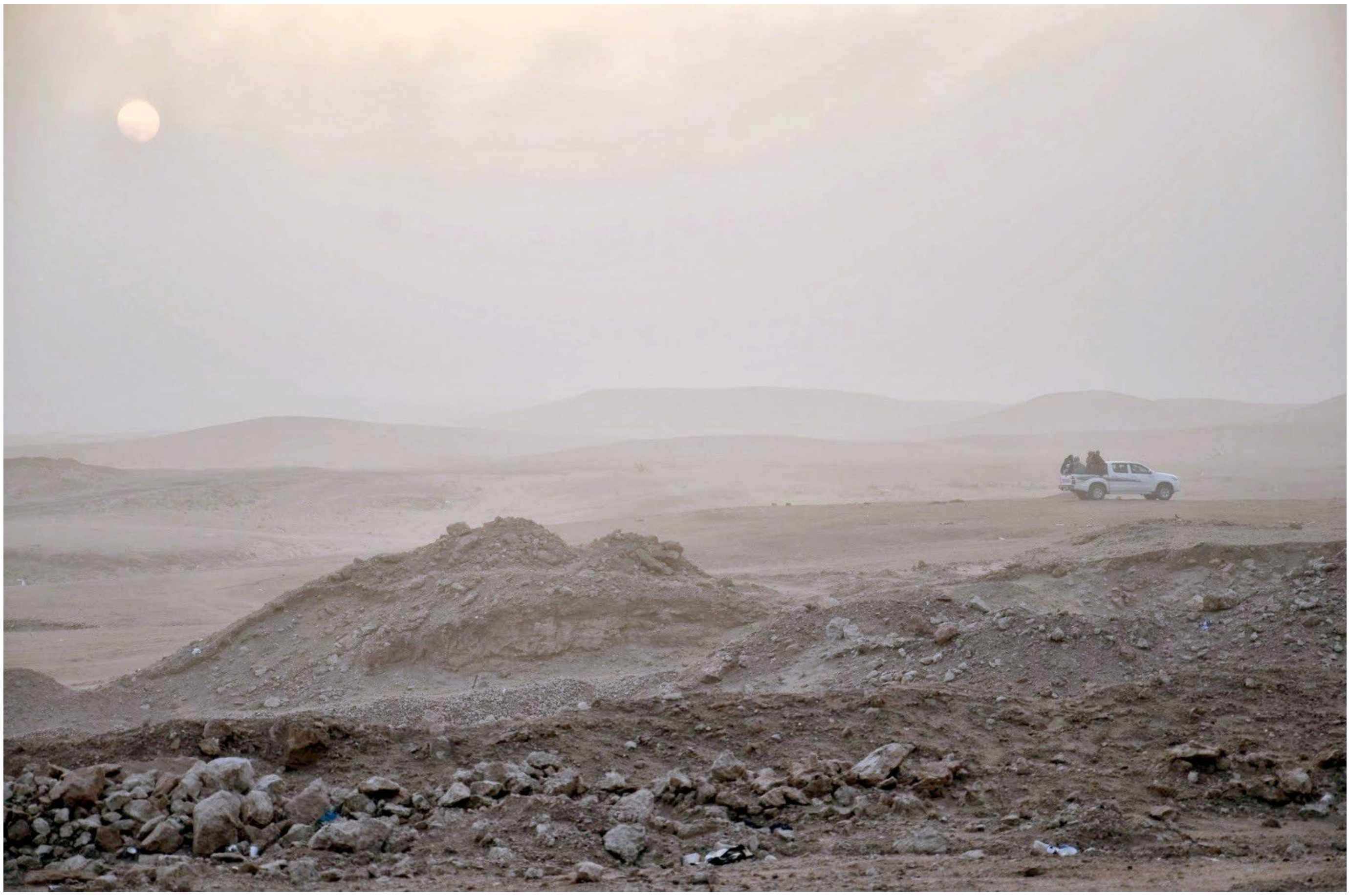
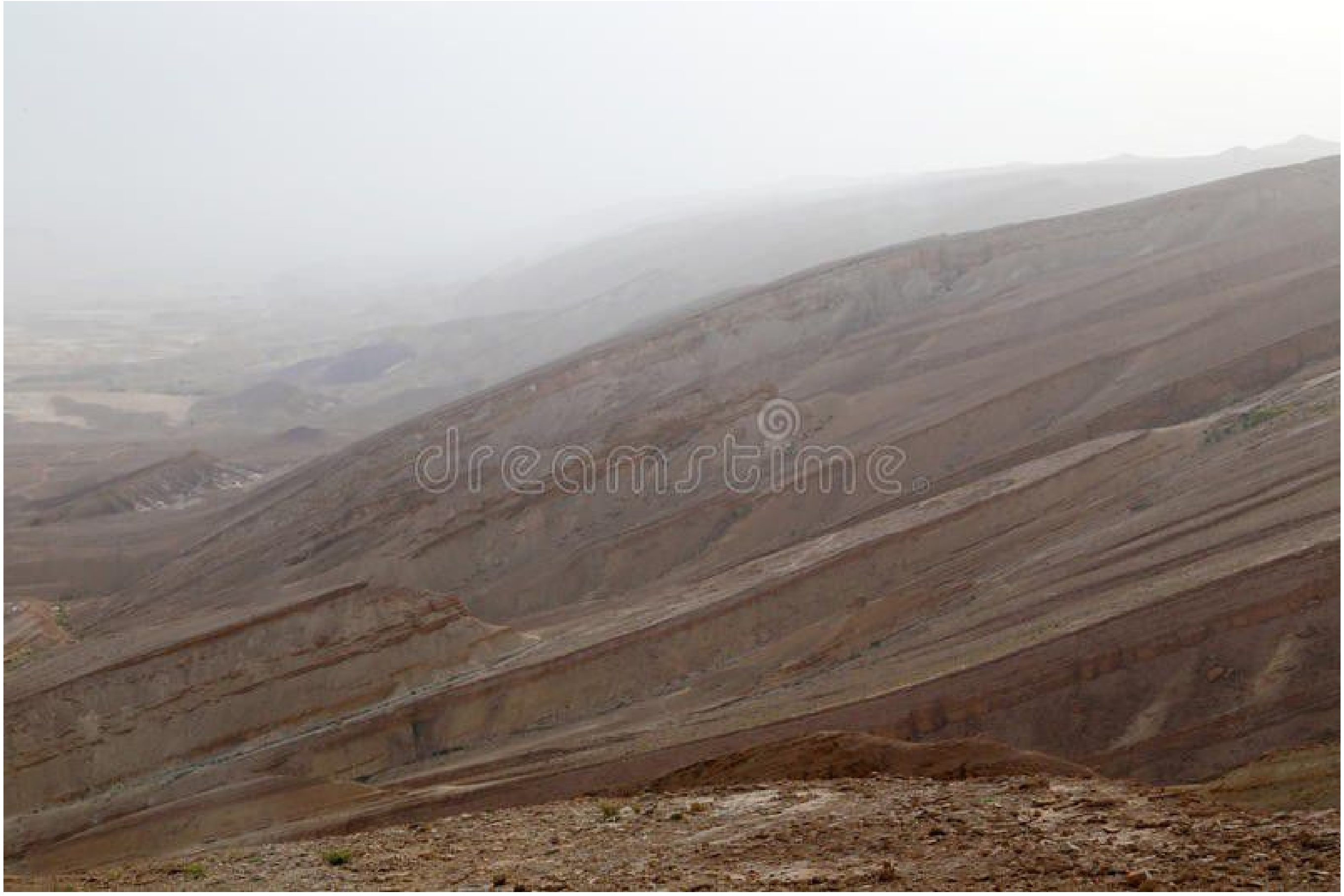
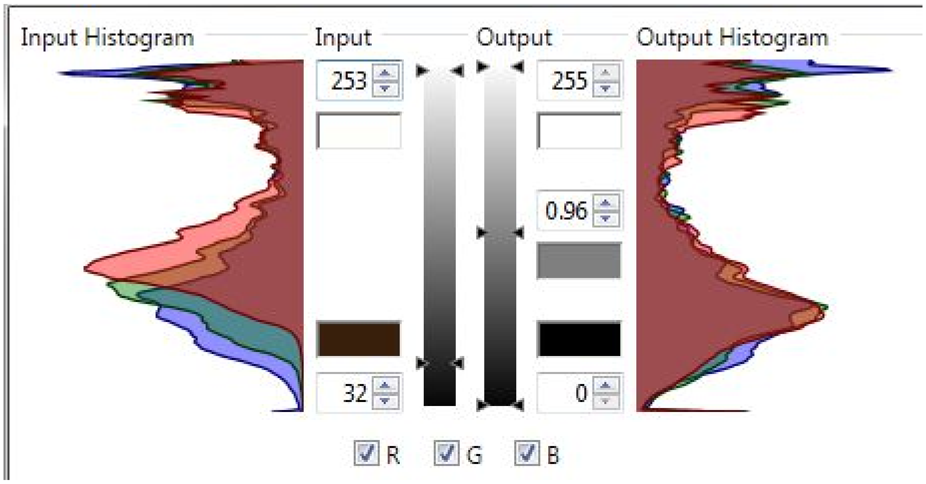


Exhibit C

This next image will focus on something in addition to what we have been examining. Earth of course has green plant matter that Mars does not. What does inclusion of plants do to the color level balance?

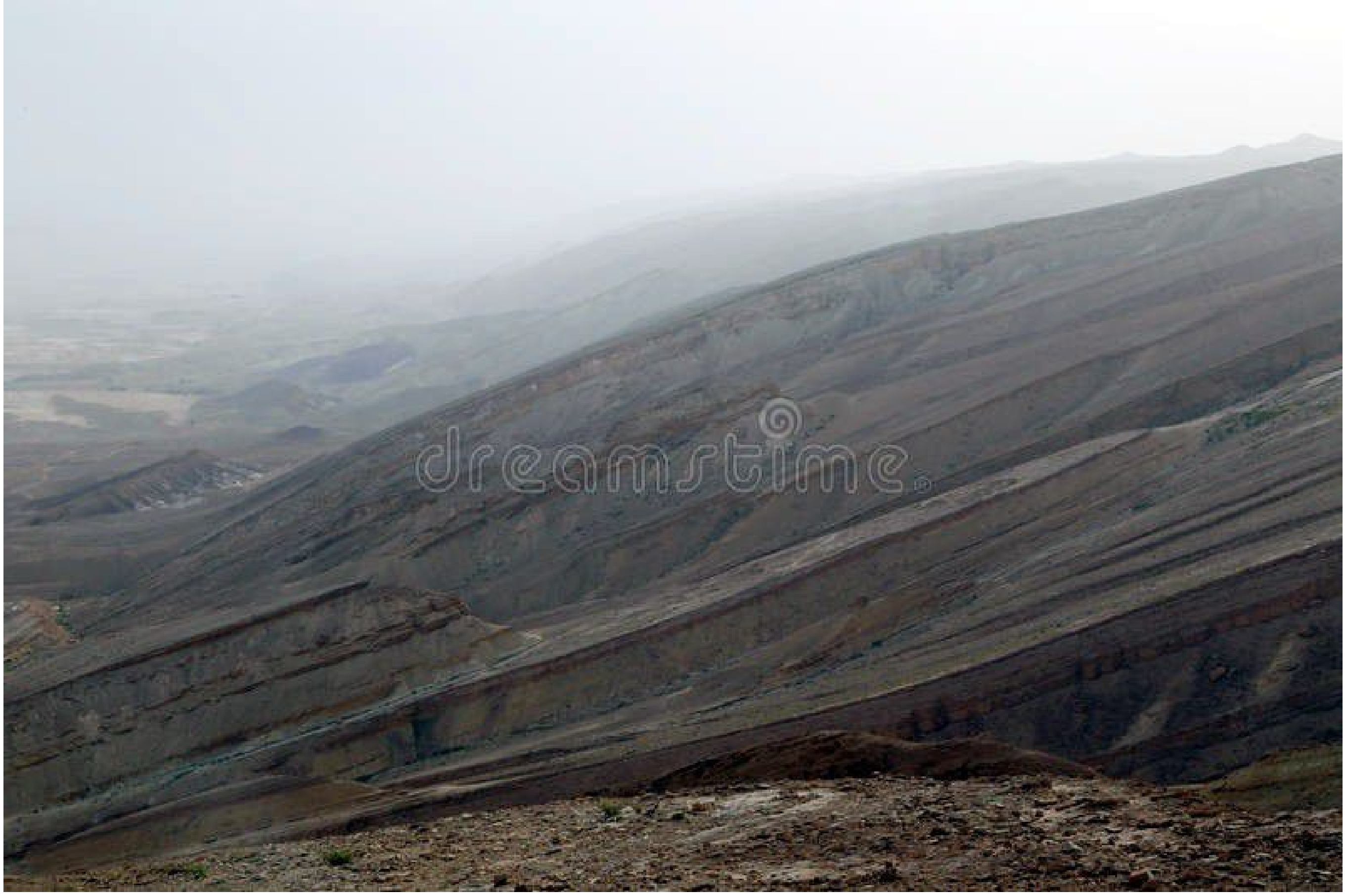

dreamstime

This image has a few plants in the extreme foreground and the mid ground hills are covered in green which is being obscured by the mist. Notice as well that as each subsequent hill gets further away toward the horizon, that the detail also fades into the mist. I keep pointing this out for these three images for a very specific reason that will become more apparent shortly.



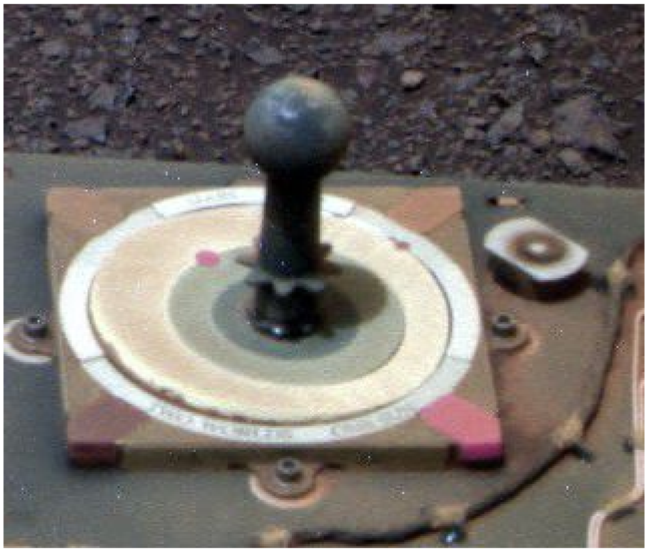
253
32
255
0.96
0
☑ R ☑ G ☑ B

The color level channels for this image are especially clear. On the left you can see that each individual channel is very similar in structure and intensity but each is offset. On the right, the channels have been modified to be more synchronized.

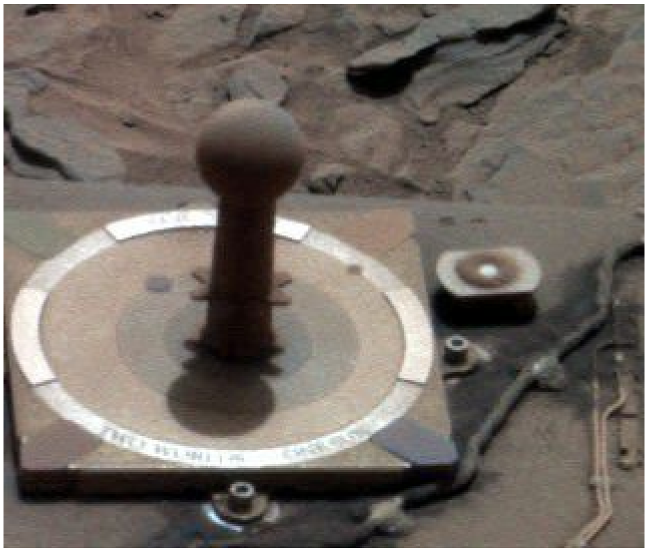

dreamstime

The resulting image tones down the red level significantly. The green hills become much more apparent. The colors that you would expect show up much more true to their actual hue.

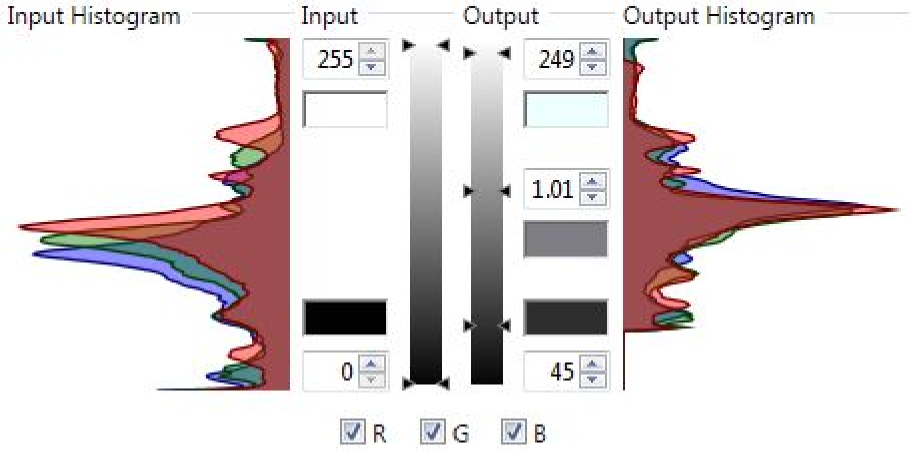
Mars Images



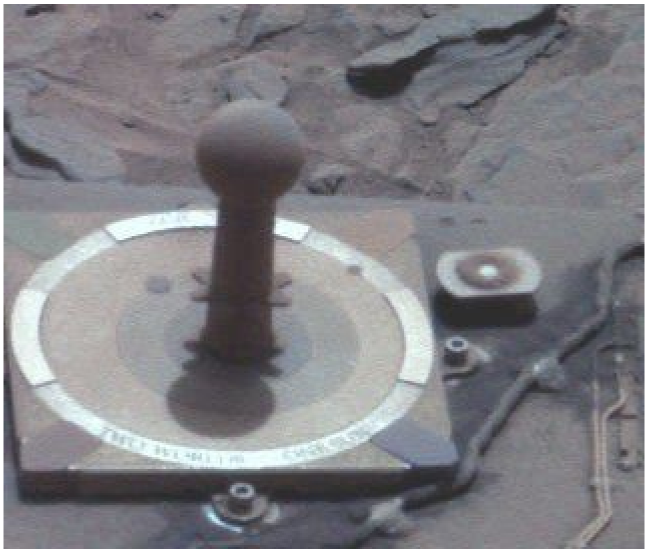
The previous 3 image investigations have led to several major observations. How can these then be applied to various images from Mars? There is one aspect we have to mention first. That is the color swatches that the various Mars rovers have on them. These swatches are of known color values and can be used to calibrate the images. There are some people who say there is evidence that image colors have been significantly modified and they use images of the swatches as evidence. For example, the image to the right.



Here is another image of the calibration swatches. Notice the colors are completely different. Which one is correct? Which one is real? Actually, they both are. The second image is a what a human would see in the visible spectrum. The rovers all have cameras with the ability to take images in non-visible spectrum wavelengths. When this data is then used to construct RGB images, a false color image is the result. That is what the first image above represents. It seems that people who state the swatches aren't being used correctly are not aware that some images are the result of non-visible spectrum data and falsely use this as evidence.



However, even the color levels of the visible spectrum image shows channels which are not synchronized which would suggest that the colors are not actually correct.

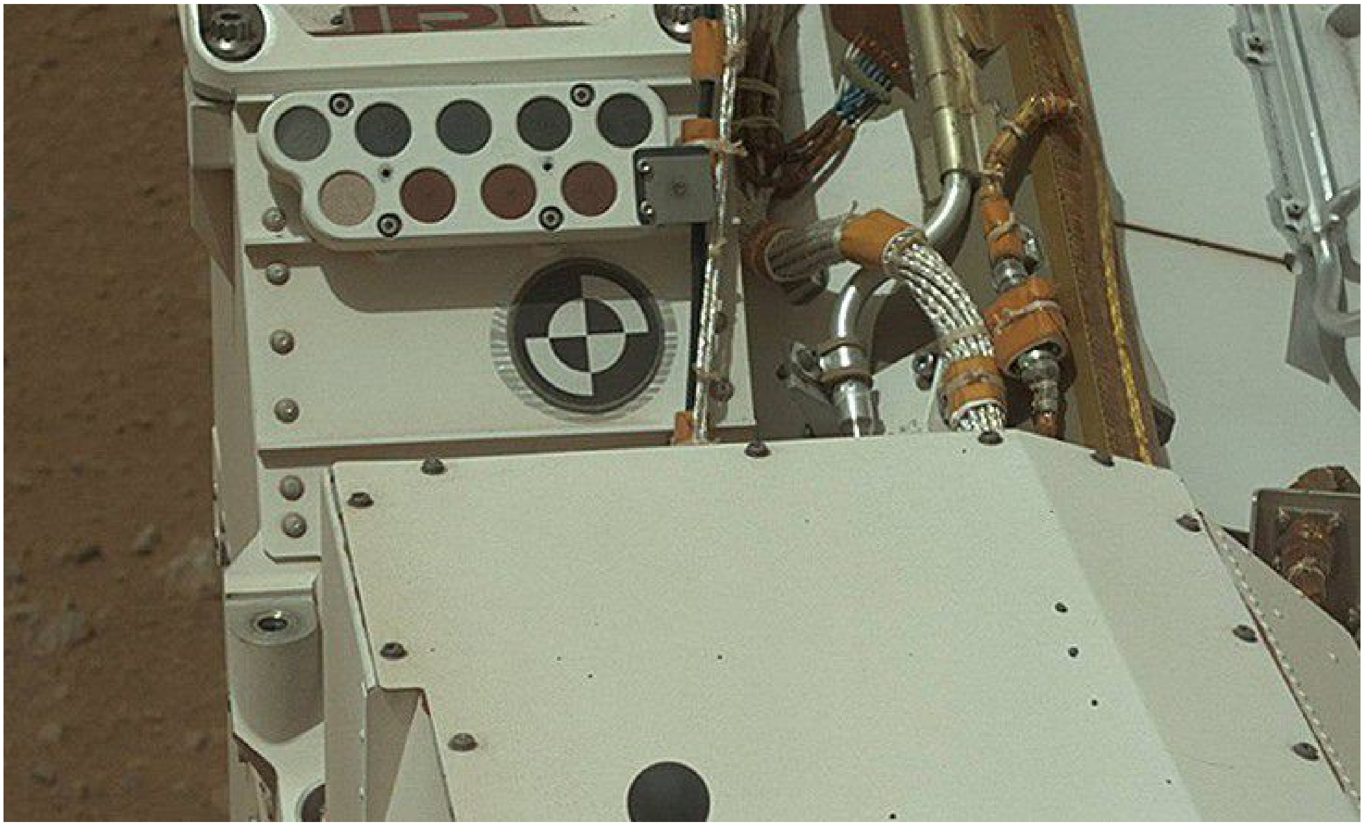


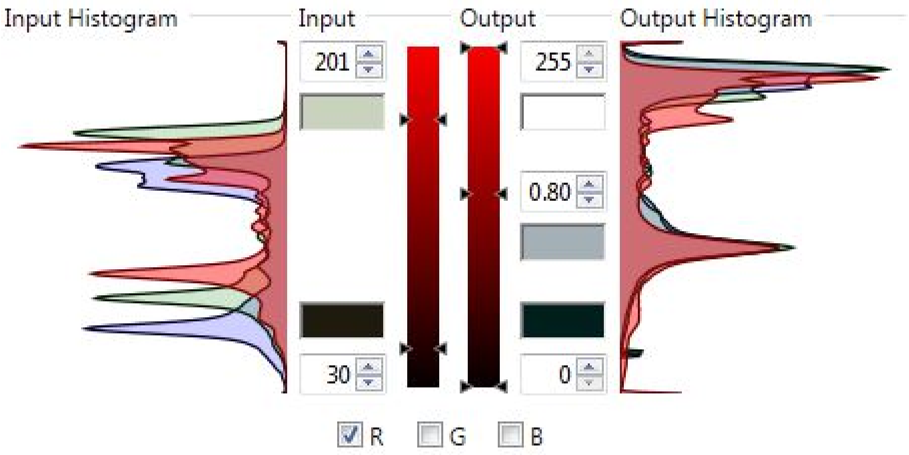
When they are matched up and the overall image lightened so that the shadow is not so stark (as would be in daylight), then the swatches become even more hue accurate. This would seem correct when comparing the sphere of the compass between the two images. In the original image, the sphere has a very reddish tint. It is supposed to be dark grey as the modified image better displays.

https://www.theverge.com/2014/8/20/6046609/its-hard-out-there-for-an-interplanetary-robot

The link above is to some very interesting images. They show the state of the rover after 2 years of service. There is an image of color swatches and the effects after exposure to the environment. We can investigate the color levels of each image.

First Year



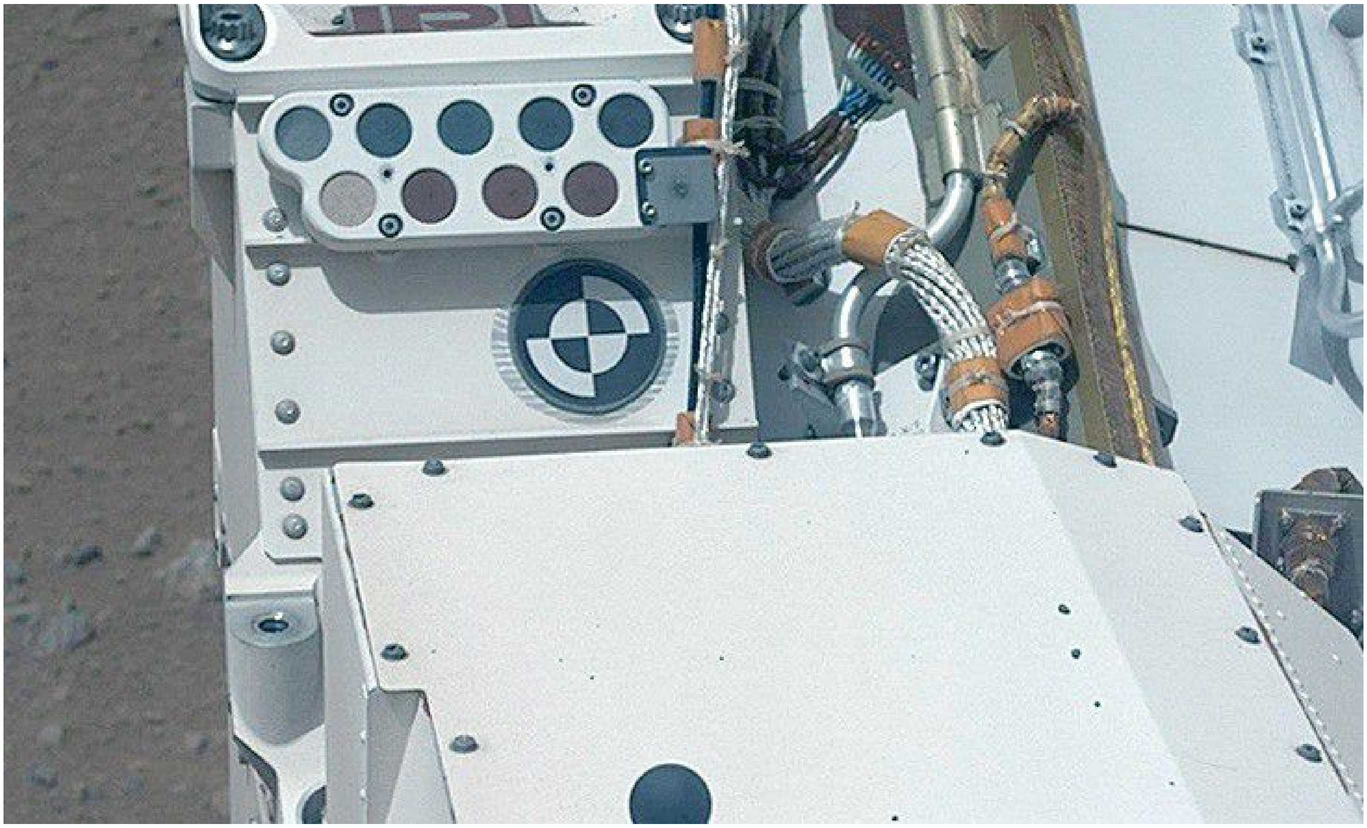


Input 201 30

Output 255 0.80 0

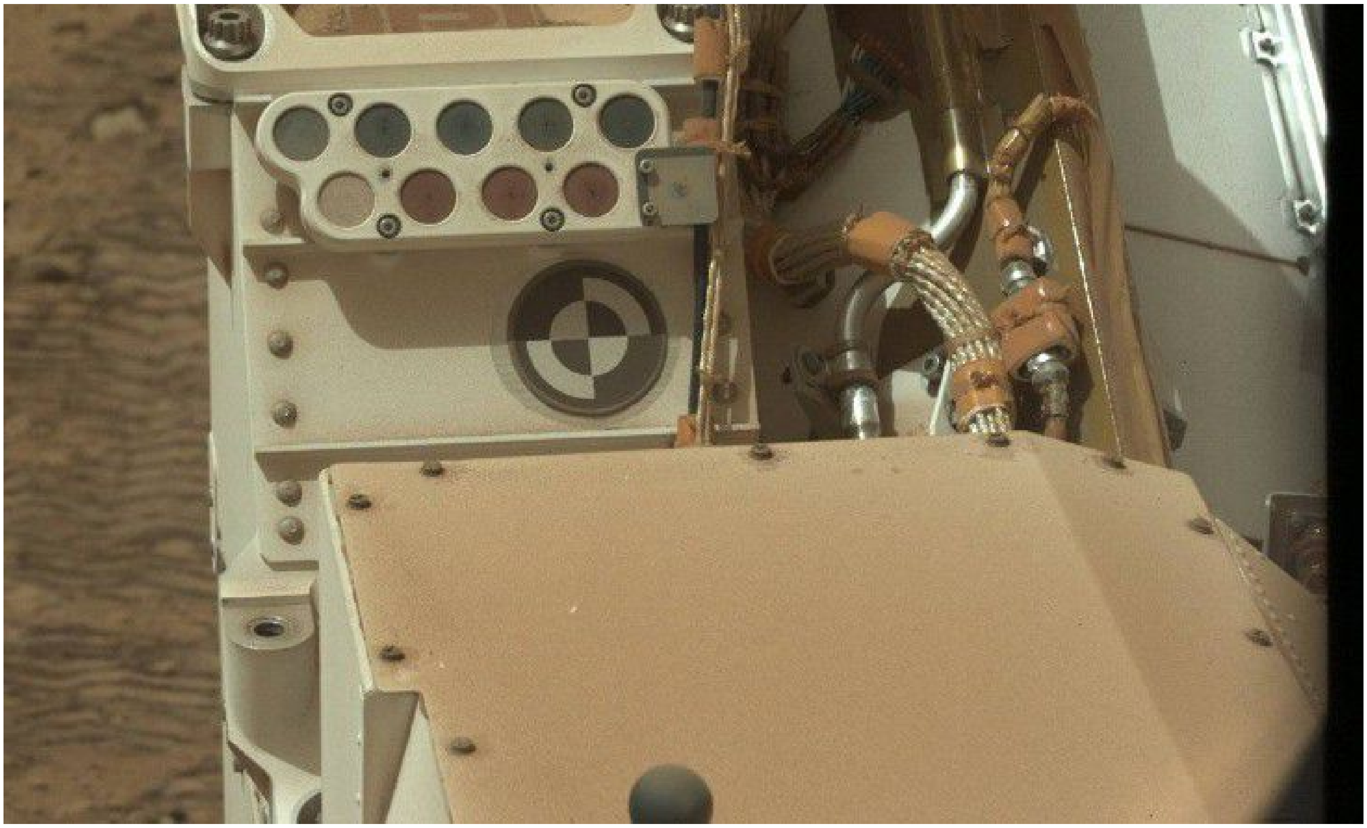
☑ R ☐ G ☐ B

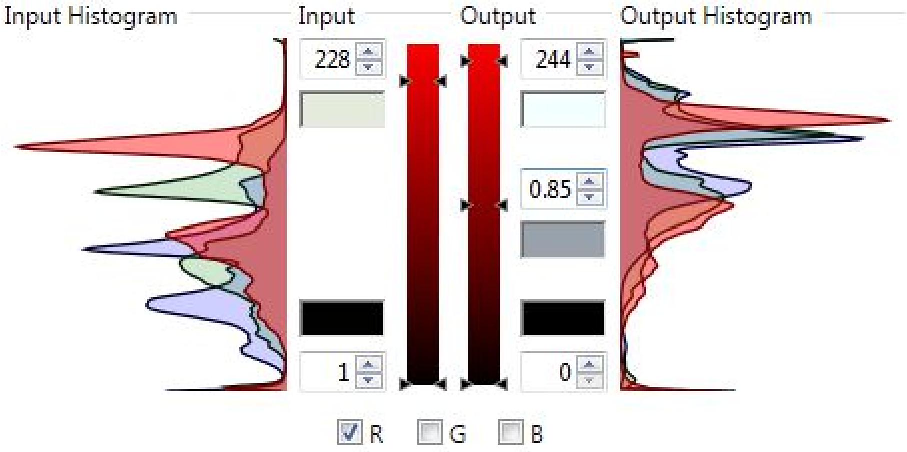
Officially released image of the rover at the start of Year 1. The rover should be in pristine condition with very little dust coverage. The image has a very noticeable orange tint. If there is supposedly so much dust in the air that an image of objects so close to the camera have a noticeable tint due to dust, the shadows would not be that distinct and clear as is shown in the image. Instead they would be much softer and indistinct. Also, there are very sharp highlights on the silver metal. This is a further sign that there must be strong sunlight present and not a sky filled with dust.



Here is that same image but with the color levels synchronized. The colors are much more hue accurate. The contrast seems more accurate as you get a sense of strong unfiltered sunlight.

Second Year



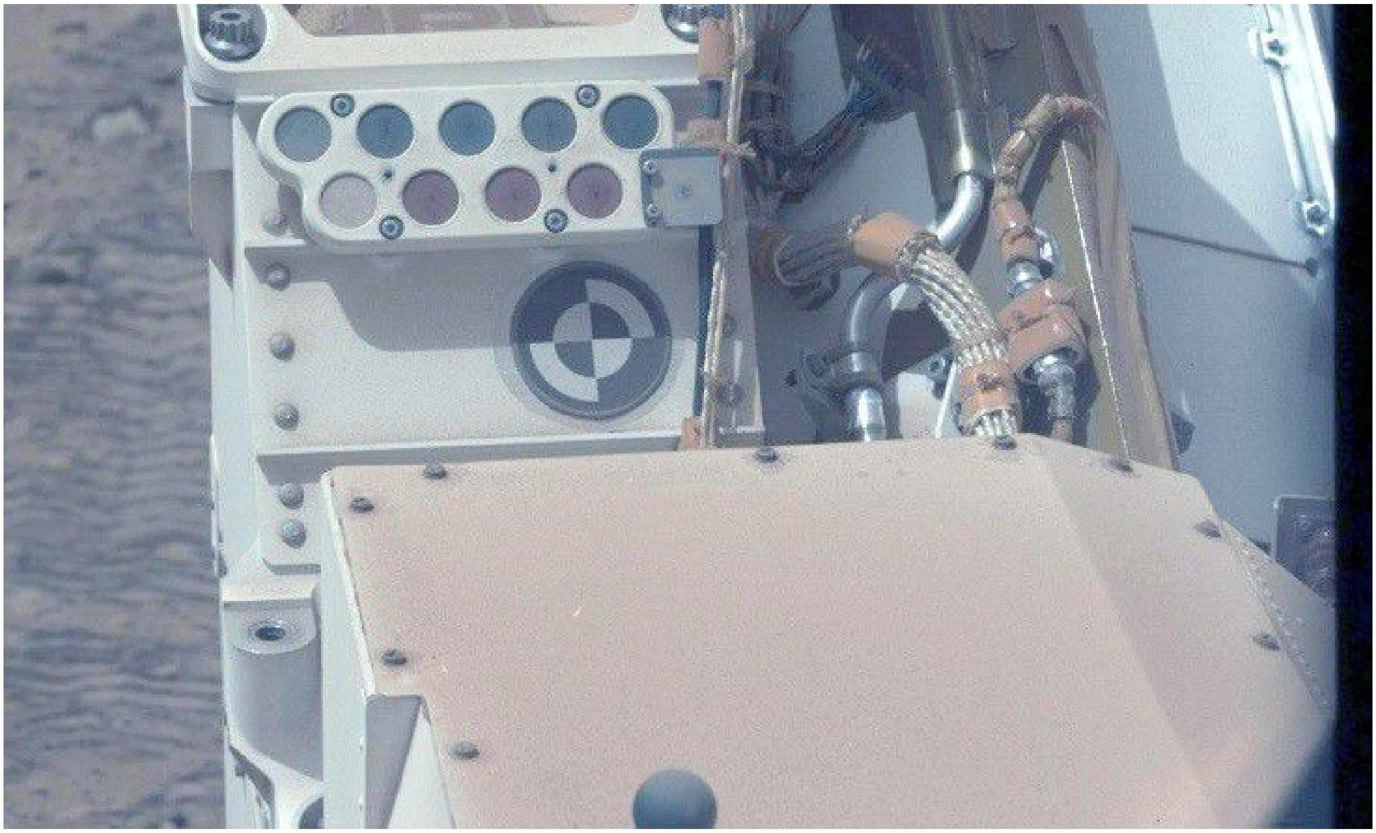


Input: 228, 1

Output: 244, 0.85, 0

☑ R ☐ G ☐ B

Here is an official image of the rover after 2 years in the environment. Everything is orange. Again modifying the color levels as best as possible results in an image with white levels quite a bit less orange. The hues end up being much more true.



Discussion

What does the examination of all these images tell us? Are there any general concepts we can apply as more images are examined?

1. An image that is being significantly affected by the sun (sunset or directly aiming toward the sun) will skew the color levels toward yellow/orange. This will happen even if there is airborne particulate (ie. dust, fog, etc).

2.Objects in sunlight result in hard, distinct shadows. When the sun is obscured, shadows are much more soft and indistinct.

3.When there is significant airborne particulate and as one looks further toward the horizon, objects will have fewer distinct details and they will take on more of the color of the airborne particulate. That is, things fade into the distance. The more significant the airborne matter, the faster things fade into the distance. If an object is a few feet from the camera and is being affected by airborne particulate so that its true color is significantly tinted, it is impossible for there to be direct sunlight in the environment.

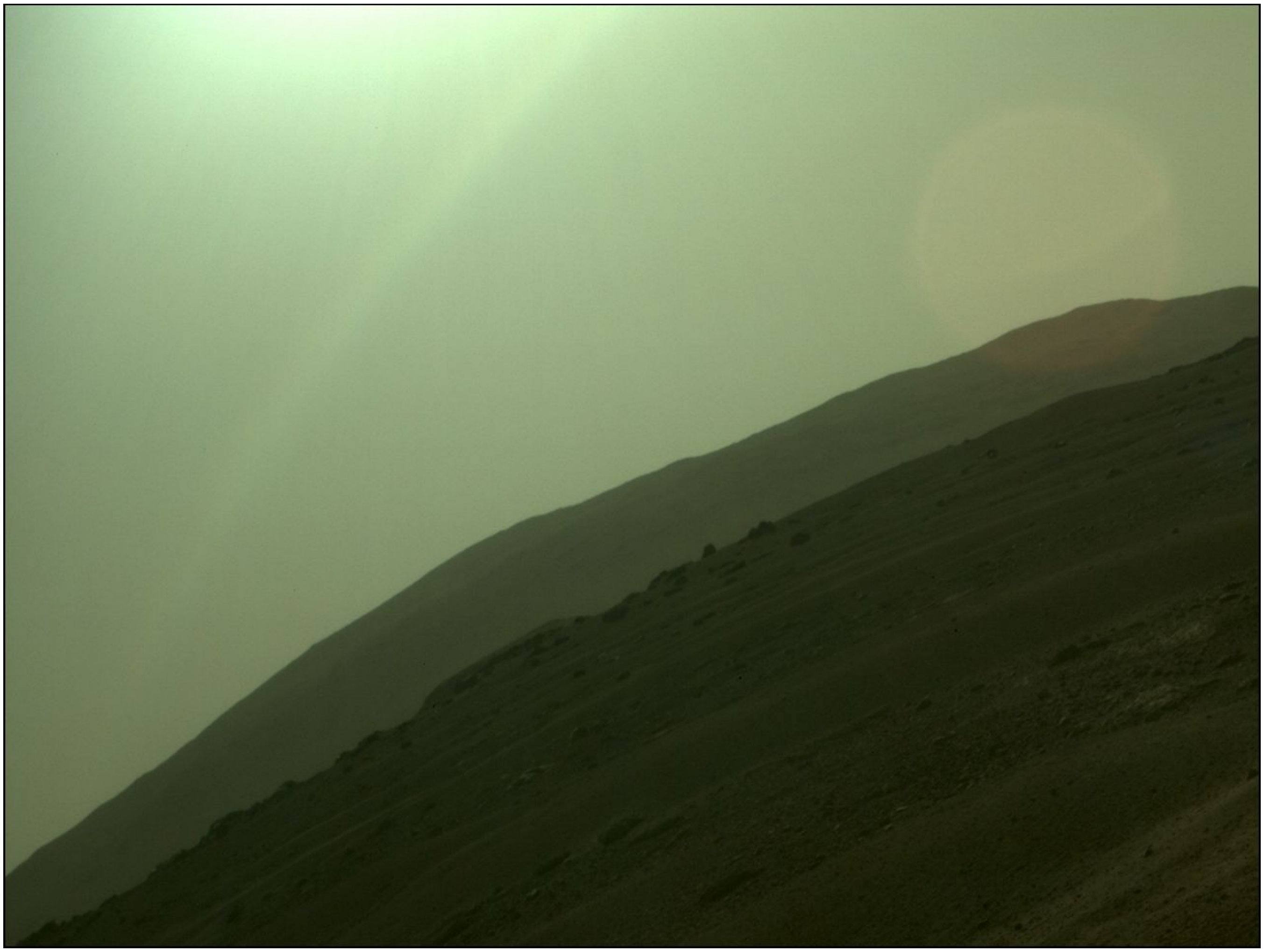
4.If there are camera lens artifacts, then there must be unobstructed light rays in the field of view. Scattered light can not be diffracted.

Part 3: Impossible Mars Images

I was combing through the latest images from Mars. Sol 9 - Feb 28, 2021. For this particular day several images were officially released which just can not be possible as presented. You can find the source here:

https://mars.nasa.gov/mars2020/multimedia/raw-images/RLF_0009_0667754763_536EBY_N0030000RHAZ00102_01_0LLJ

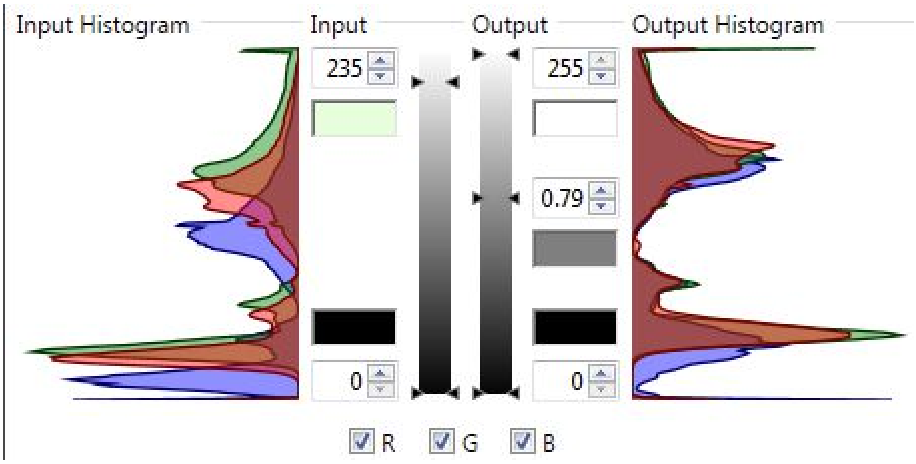
Here is one of the official releases.



It's another "rainbow" on Mars. Actually it's a lens flare artifact. In addition there is a round flare artifact due to the camera catching the lower sliver of the sun in the view. There is a noticeable greenish tint to the entire image. This is an impossible image.

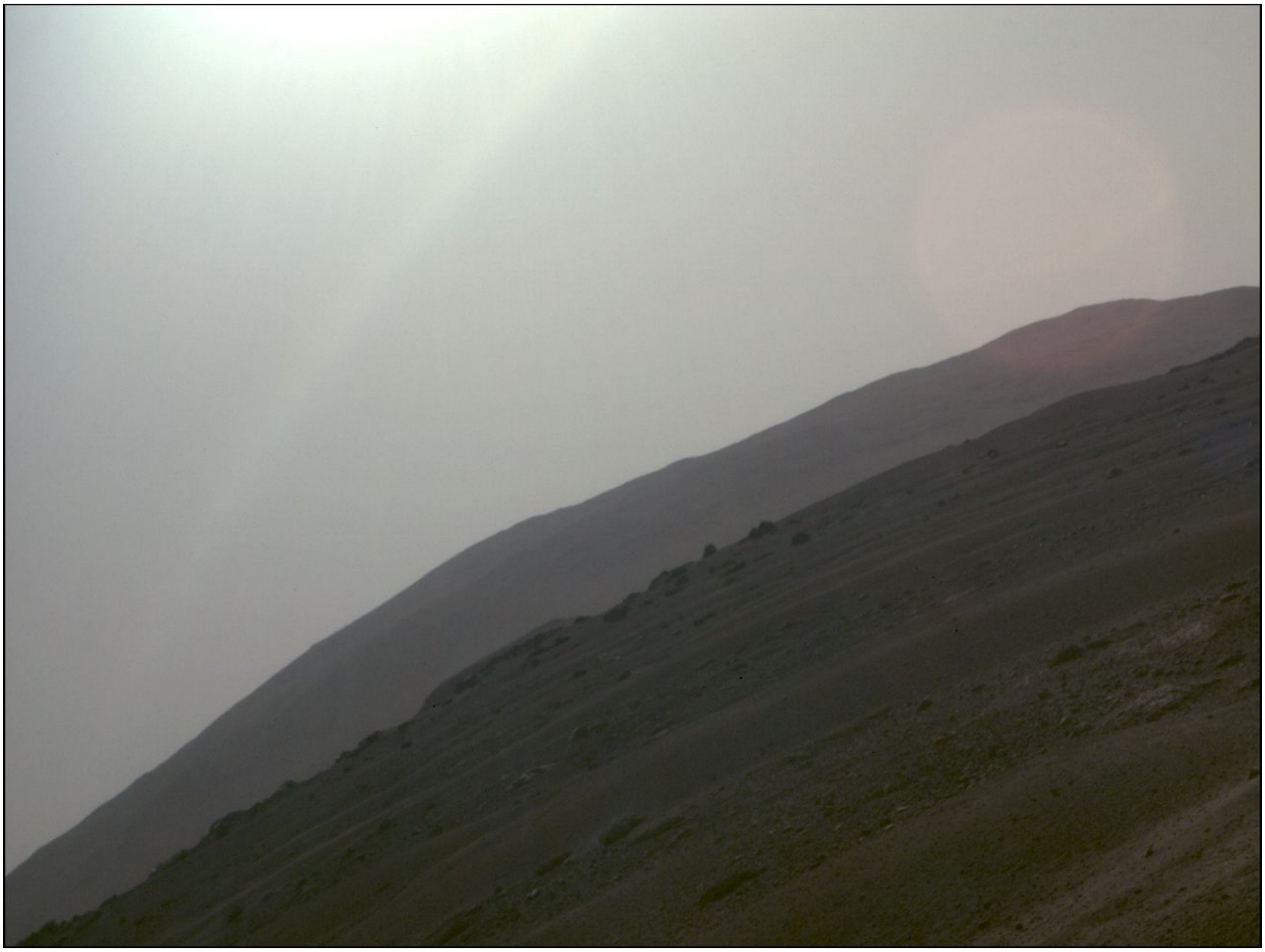
First, let's examine the lens flare artifacts themselves. The hues of the artifacts are all skewed to green. The round flare should be red, not brown. Light that is diffracted splits into pure rainbow hues. And this flare is happening inside the camera housing and not in the environment. The color of the artifacts should not depend at all on the color of the subject matter.

Second, this image has been calibrated with the usual settings for images from Mars. For this image, this results in a green sky. We are told that the atmosphere on Mars constantly has suspended dust particulate and this makes everything look red-orange. However, this image clearly shows 2 lens flare artifacts due to the camera including the sun in the view. Lens flares are impossible if there is a lot of dust or fog obscuring the sun. In this case, if there is so much dust in the air which results in the sky turning greenish, there would be no unscattered light beams able to enter the camera housing and causing lens flares. It's impossible.



235
0
255
0.79
0
☑ R ☑ G ☑ B

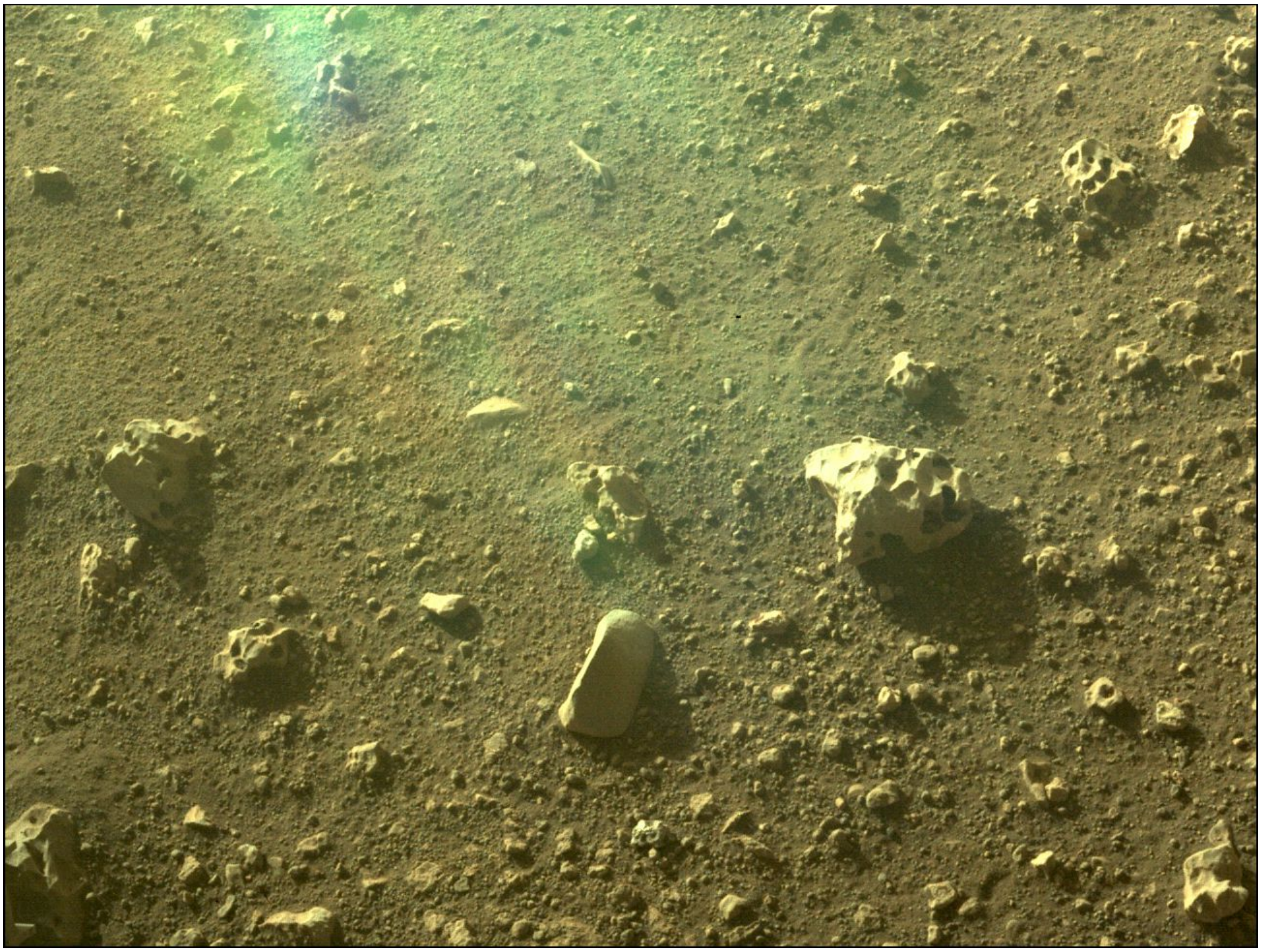
Looking at the color levels for the image the 3 channels are very similar in structure and intensity. If they are modified so that they are more synchronized, this has a significant effect on the image.

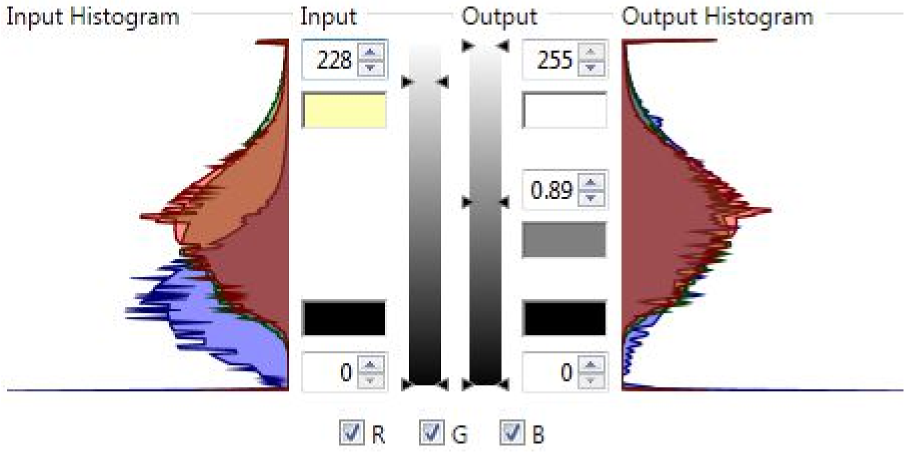


Now the image makes much more sense of the physics being displayed. The lens flare artifacts are shown true to hue. Since there can be very little dust in the atmosphere, the sky is now blue. The rocky landscape also has much more detail evident.

Exhibit 2

Here is an image from the bottom of the rover captured on that same day. Obviously it is very near to the ground. Yet, it still has a noticeable yellowish tint over the entire image. Oh, and there is a significant lens flare artifact being displayed. Again, an impossible image. How can there be so much dust in the air that everything takes on a yellowish tint, yet the shadows are so distinct and there are unscattered light rays which are able to reach the camera housing and diffract into lens flare?





Input: 228, 0

Output: 255, 0.89, 0

☑ R ☑ G ☑ B

Here are the color levels. The blue color channel is significantly offset from the others. But when they are all synchronized, a much different image results.

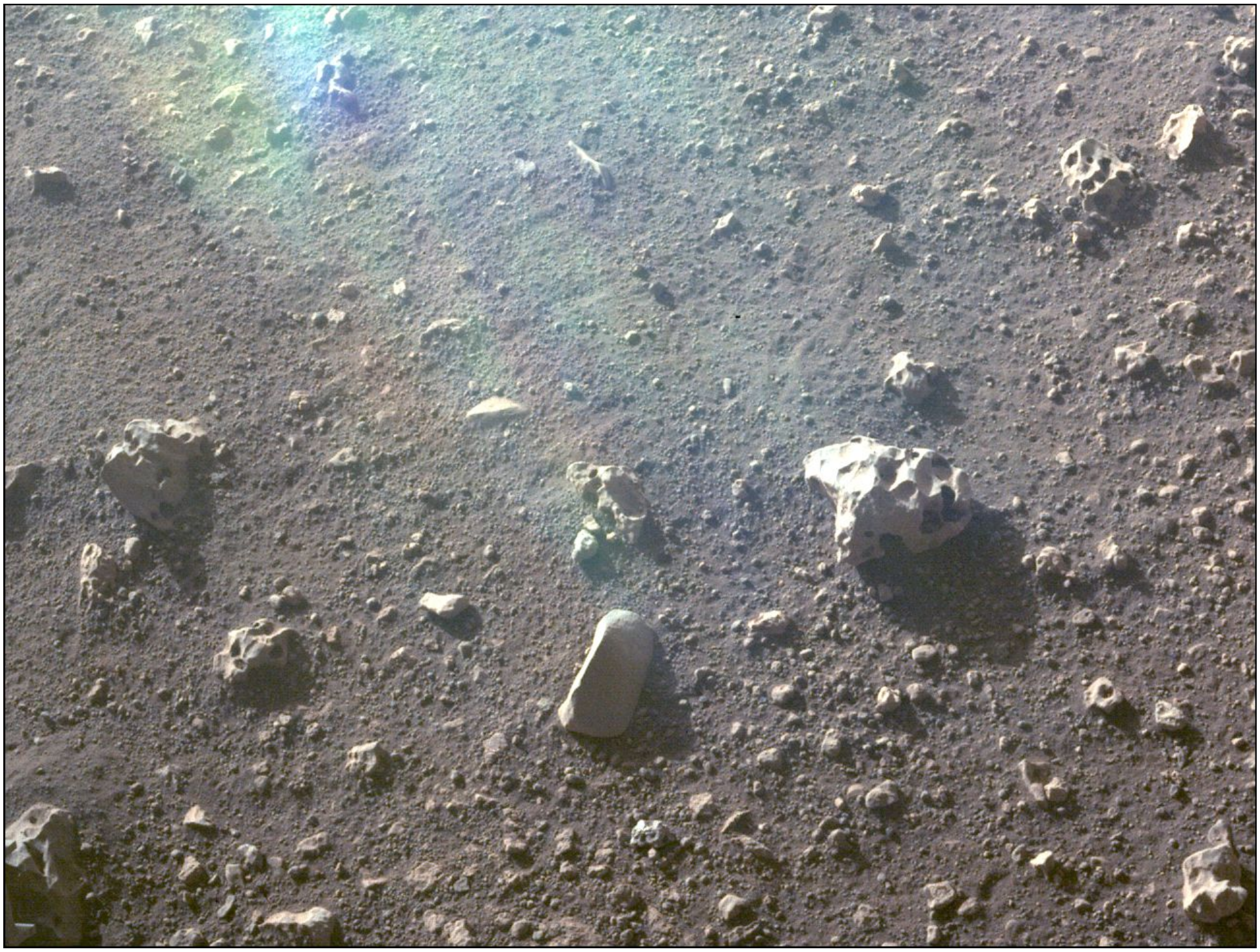
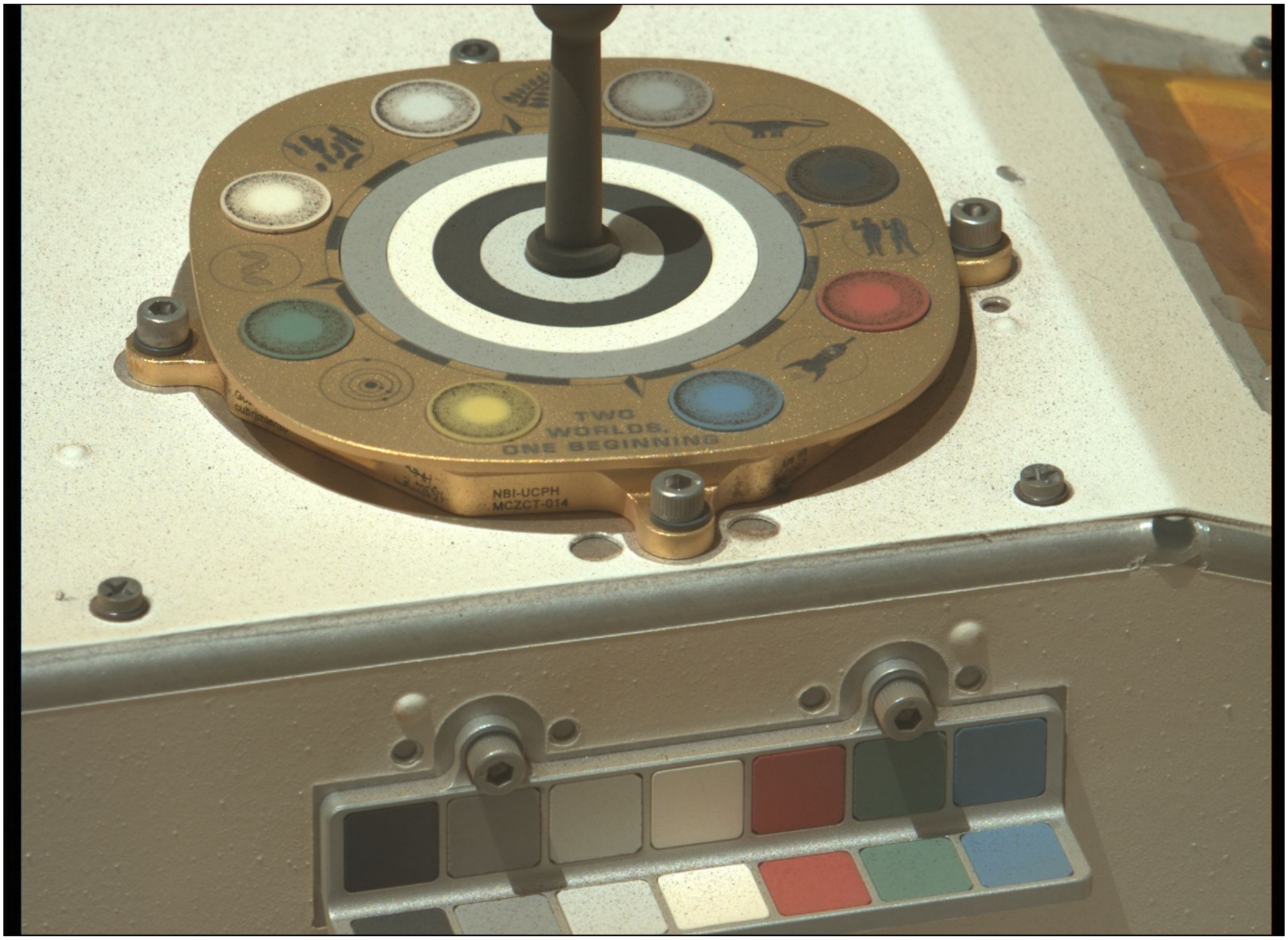
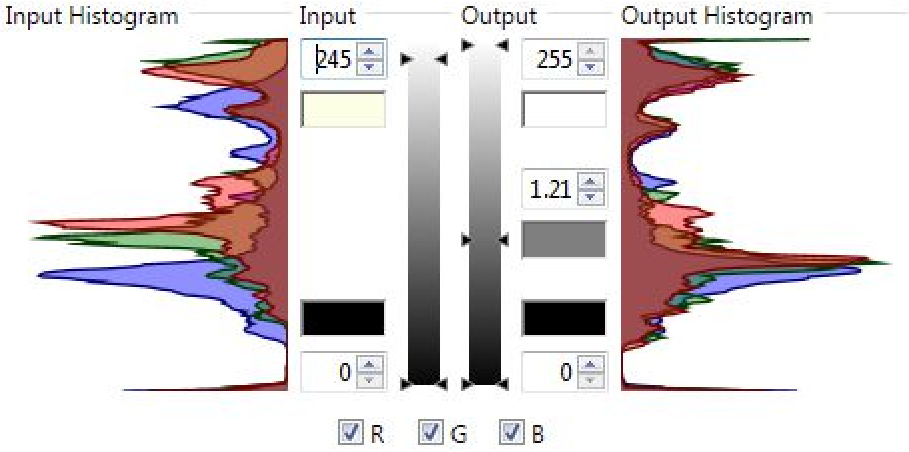


Exhibit 3

Which of these images are more accurate? Is there some way to tell? The rover has color swatches which can be used for color calibration. Here is the image taken on that same day.

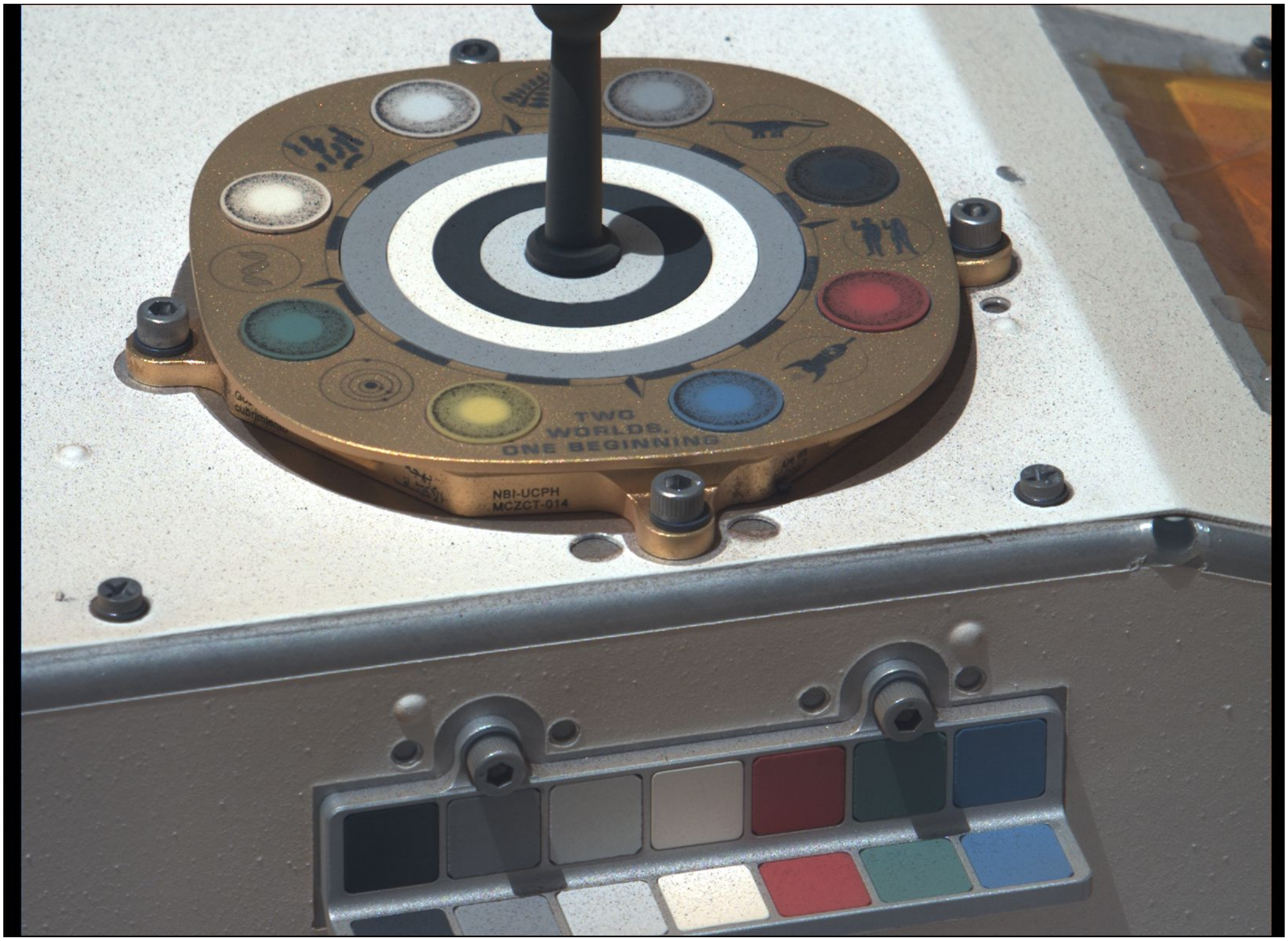


However, again the entire image has an overall yellowish tint. Is there that much dust in the air able to affect objects that close to the camera?



Input: 245
Input: 0
Output: 255
Output: 1.21
Output: 0
☑ R ☑ G ☑ B

Again, examine the color levels and modify them to more closely match.



The resulting swatches are much more true to hue. The white of the rover housing displays the state of the newly arrived rover much more accurately. And the sharp, distinct shadows match that of a clear sky sunny day. This goes a long way to validate that making these type of color level modifications results in a more accurate photograph.

So the question is: does anyone else notice these same issues with images from Mars?

Part 4: Mars Photos – A Technical Investigation

Over the past few articles, I have been examining various topics generated by photographs from Mars. The simple question of what would humans see if they were on Mars seems to be a very contentious question. There does not seem to be a clear answer. Of course, NASA assures us that their officially released images are based on the very best data available. Many people are satisfied with that answer. However, if one has has some rudimentary education in physics and looks at the images with an inquiring mind, there are questions that result.

That is what I hoped to highlight in these articles. There have been heated discussions since the very first Mars photograph was beamed back to Earth in 1976. There seems to be no way to come to a definite answer. The same arguments are regurgitated after each subsequent mission to the red planet. However, I believe there is a major new piece to this whole issue that has not yet been recognized. I believe it will add some scientific evidence to the issue and counter the opinions of the experts which we have had to settle with for decades.

This new piece to the puzzle comes from the observation that the latest Perseverance rover has cameras which have sent back photos with lens flare in them. As far as I can determine, there have never before been any photographs from Mars that have had lens flare occur. If there have been some, it is not many. This is a major development and a significant area of new research. Why is there lens flare? What causes the lens flare? What does that say about the environment that the cameras are photographing?

My previous articles had as the stated goal to determine general observations based on the physics that are visible in the images. This was not based on any technical data about specific cameras or mission parameters. It was simply taking the officially released photos at face value and the assumption that they accurately displayed what a human eyeball would see if they were in the same environment on Mars in those conditions. This is why I labled some photographs "impossible". It's not that the images can't be manipulated in some manner in computer software. It's a response to the assumption that those official photographs represent what a human would see on Mars at that particular time, in those conditions, and at that location.

Here again are the general principles which I have discussed:

1. An image that is being significantly affected by the sun (sunset or directly aiming toward the sun) will skew the color levels toward yellow/orange. This will happen even if there is airborne particulate (ie. dust, fog, etc).
2. Objects in unobstructed sunlight result in hard, distinct shadows. When the sun is obscured and light rays are scattered, shadows are much more soft and indistinct.
3. When there is significant airborne particulate and as one looks further toward the horizon, objects will have fewer distinct details and they will take on more of the color of the airborne particulate. That is, things fade into the distance. The more significant the airborne matter, the faster things fade into the distance. If an object is a few feet from the camera and is being affected by airborne particulate so that its true color is significantly tinted, it is impossible for there to be direct sunlight in the environment.
4. If there are camera lens artifacts, then there must be unobstructed light rays in the field of view. Scattered light can not be diffracted.

These principles are based on my understanding of physics and optics through what I have studied and observed. If they are not correct, I do hope that evidence can be shared to show otherwise. I continue to actively search for information that may disprove these principles. Why? If these principles are accurate and they are applied to the various photographs from Mars, I believe that the officially released photographs are extremely inaccurate. They do not represent what a human would observe on Mars.

Since the previous articles contain little technical information, I wanted to spend some time on what information is available that can further add to this discussion and inform these conclusions.

The following topics will be investigated:

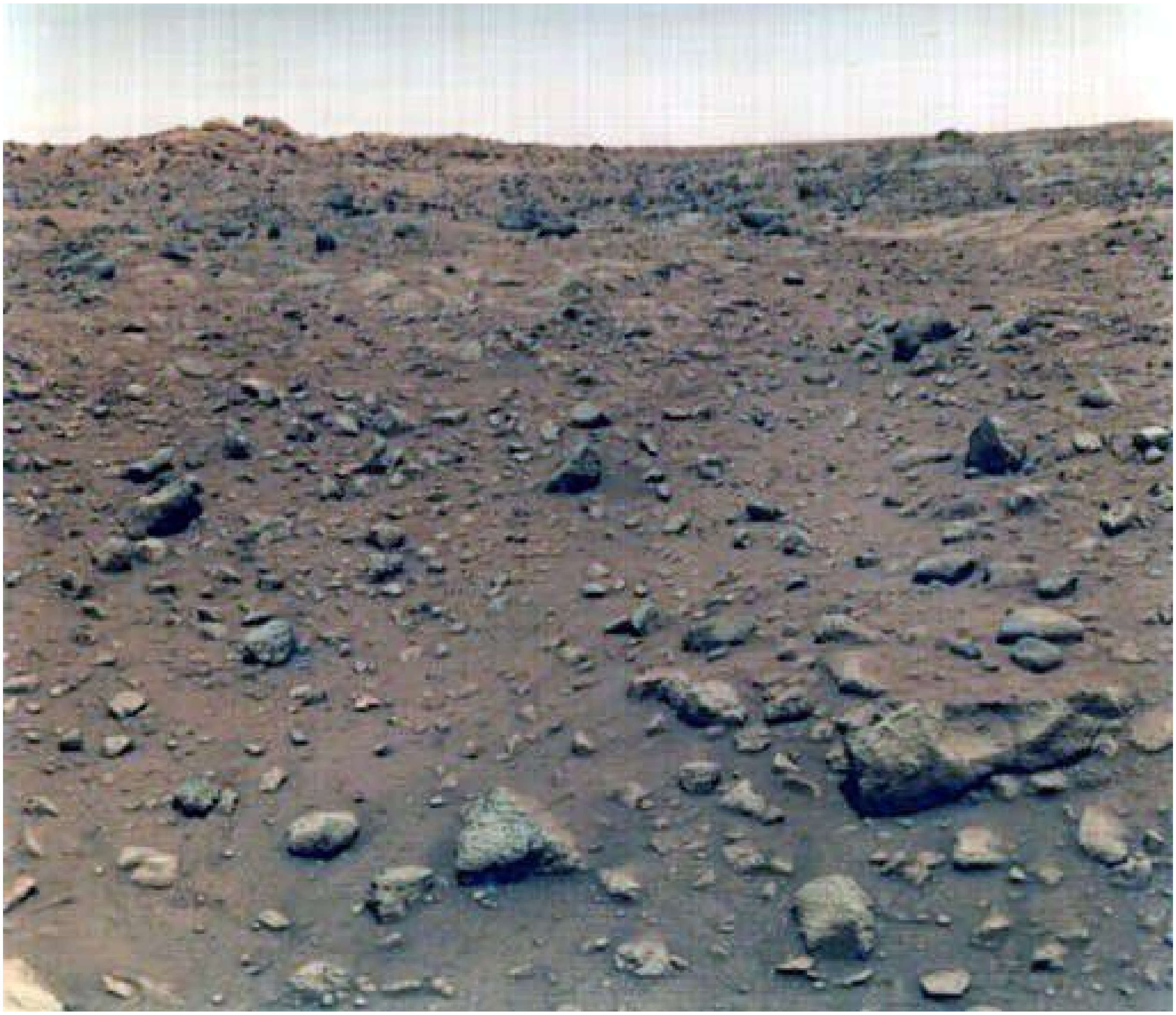
1. What is the history of color calibration for Mars photographs and why has it been so difficult to come to an acceptable solution?
2. How exactly are the images generated and how are they modified?

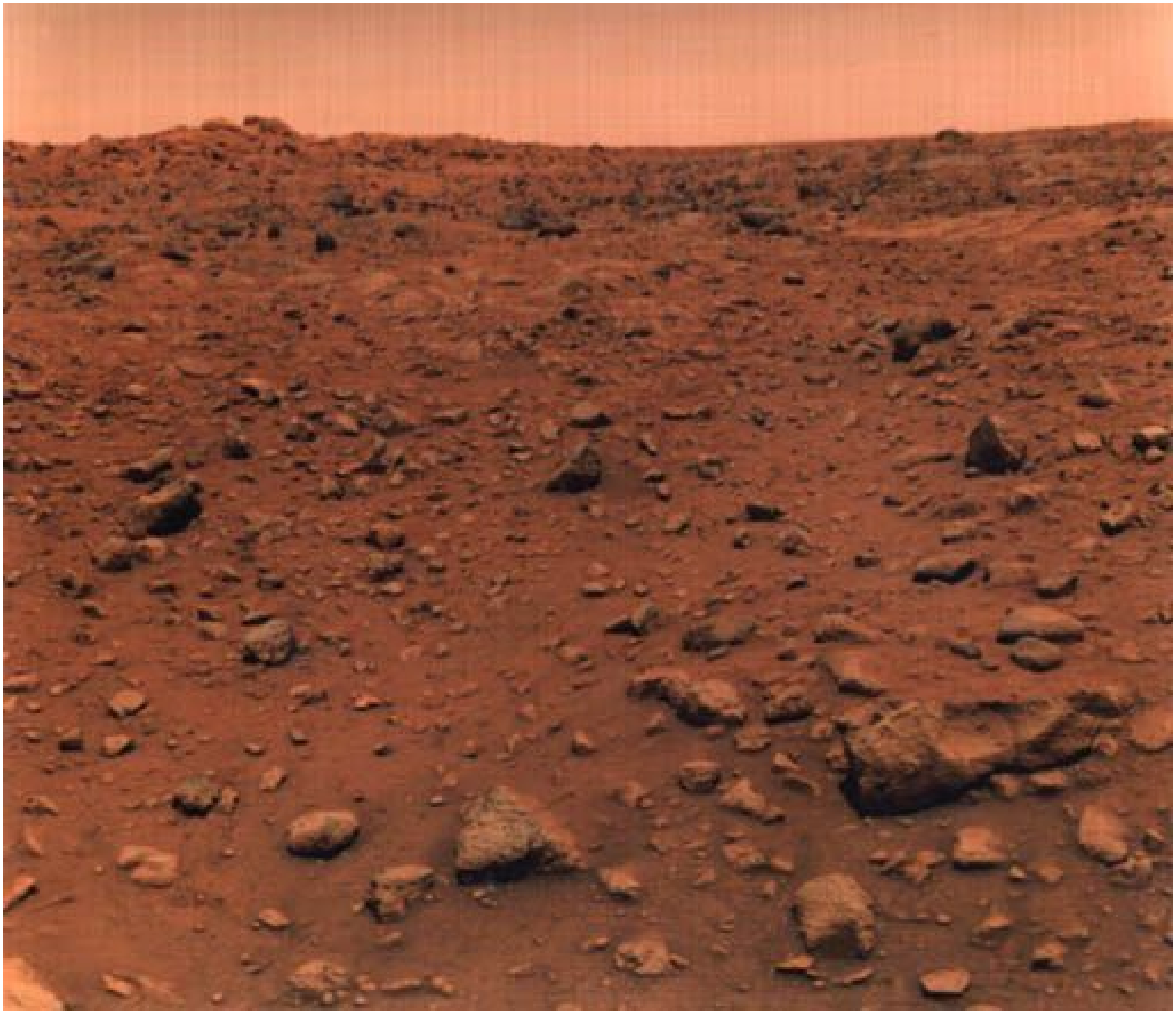
3. Why are there lens flares visible only now after 40 years of photographs from Mars?

Mars Color Calibration History

"Carl Sagan Announces Correct Color of Sky in Viking Mars Image"

On July 21, 1976 Carl Sagan announced in a press conference that the first image that Viking lander had sent back and had been released was not, actually, accurate. It had shown a distinct blue sky. One of the experts had in the meantime rechecked data and had recalibrated the image. The image now showed a pinky-orange colored sky with a distinct reddish tint over the entire image.





First Mars image with color recalibrated.

The obvious question is how could they have gotten it so wrong?

Here is a paper written in 2004 which examined the process of color calibration of photos from Mars.
"Color Calibration of the Martian Images"

Ron L. Levin
2004
http://www.gillevin.com/Mars/5555-29.PDF

Levin states *"there has been a great deal of difficulty producing color images with a consistent color balance. For the first several hours, the images were shown to have a blue sky with some greenish areas on rocks. After that, a major recalibration was performed, which rendered these Viking images in a much redder tone with a red or pink sky, and the green areas replaced with gray. Several hours after that, the images were recalibrated again with the sky moving toward a more neutral pink, the areas on the rocks remaining grayish."* He concludes *"in the last 28 years, large variations in the coloring of published Martian lander images have failed to coalesce into a consensus. The reason given for this wide range of image color calibration is the uncertainty in the color calibration caused by unknown Martian illumination."*

Another source of processed images from Mars, created by Holger Isenberg, discusses the historical issues and is found here: http://areo.info/mer/

He states: *"There has been much discussion on the Internet how complicated the reproduction of true color images from Mars would be. Of course, a 100% precise reproduction is not possible as the human visual system can only be approximated by technical devices. Taking this fact, some scientist claim, that it is impossible to recreate the Martian colors. These scientists forget that on Mars the same Sun is shining as on Earth with just reduced intensity by 40% and the same optical and physical laws are valid.*

Nobody with enough common knowledge would claim that you cannot create true color pictures on any location on Earth. Color is not always 100% correct, but the general colorization is represented so we can get the impression how it would look like on that location when viewing it with our own eyes.

However, with the image data from Mars there was controversy about its colorization since the first color image was taken by the Viking Lander in 1976. The color calibration problem seems to be unsolvable. Even today, more than one year after Spirit landed, the calibration information given at the NASA PDS MER Atlas is still preliminary. Furthermore, a small error which happened during the calibration of the Viking Lander cameras seems to be used as base for calibrations of all later missions. As the investigation on this presumably unintentional erroneous Viking calibration document is still ongoing, a concluding report cannot be given yet."

If he is correct, that means the initial flurry of investigation that happened during the Viking mission has not changed substantially in all the subsequent missions to Mars. The assumptions remain – with slightly altered calibrations.

How exactly are the images generated and how are they modified

Isenberg describes how he generates the immense catalog of Mars images based on the black and white raw data files that are available from NASA.

The images are automatically created daily from raw data available at JPL Marsrovers Gallery.

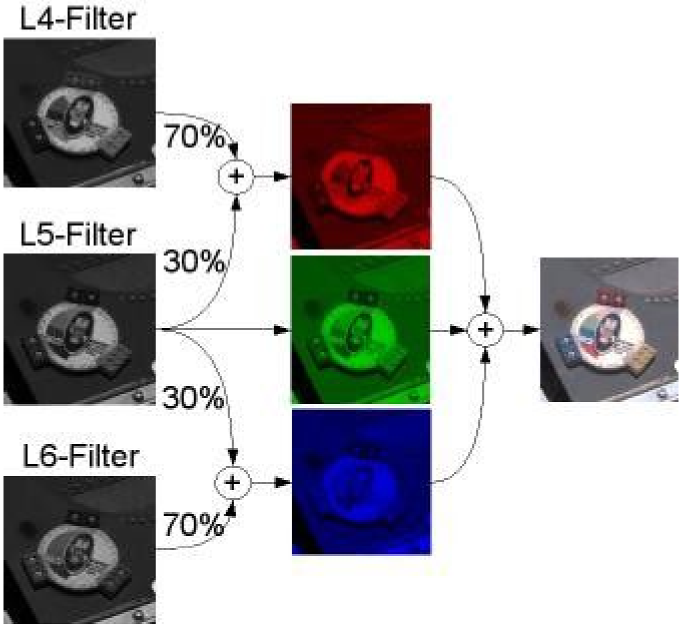


Fig.1: The image creation process applied to all images on this website (MER2RGB-process):

1. *3 raw images are taken through the red (L4), green (L5) and blue (L6) filter with the Rover Panoramic Camera.*
2. *The red and green images are combined (each pixel value summarized) with weighting 70/30; the same is done with blue and green.*
3. *The results from step 2 are combined into one color image.*

Every Martian day (Sol) new raw images are downloaded. The raw images are black & white images, each taken through a colored glass (filter) by the Panoramic Camera on the Rover. By using 3 filters, each one only letting pass red, green and blue light, a true color image can be created. This is in principle the same as every common photo or video camera creates color images.The Rover Panoramic Camera differs from normal digital cameras by having filters with smaller bandwidth resulting in images with appear as having too much color saturation. To counteract this effect a special but simple processing is done as follows:

By combining the black & white images from two filters a visual effect is created as the image would have been taken through one filter with wider bandwidth. The result is a good approximation to true natural colors.

...with the MER2RGB-process described above the overall colors approximate true colors sufficiently. That means, the soil looks still "Earth-like" and the sky is still blue to white.

What this means is that the combination of raw data for 3 channels leads to a result which looks very much like it would on Earth. That is, color levels curves are very similar in structure and intensity. This means that with my investigation over the past several articles, equalizing the color levels is simply restoring to a state of what the raw data actually was when the rovers sent that data from their cameras back to Earth.

It was on Earth that an additional color calibration process has to be done in order to modify the images to what experts consider an accurate representation.

Levin describes the additional process this way:

A roundup of subsequent published Martian lander images has shown a wide variety of scene colorations. Official published images from Viking, Pathfinder, and, more recently, Mars Exploration Rover (MER), continue to show wide variations of color. The builders of the Viking, Spirit, and Opportunity landers provided two methods for calibrating the color response of Martian imaging.

The first method was a derivation of color calibration algorithms using the flight cameras while still on Earth before launch. The actual flight cameras were used to take images on Earth, which were then used to develop color calibration algorithms. These algorithms were tested repeatedly and found to produce reliable color imaging while the spacecraft were still on Earth. These calibration algorithms were then stored for use with the digital data transmitted from Mars. This method of calibration relies on the assumption of stability of the camera instrument during the transit from Earth to Mars.

The other method of color calibration depended on the observation of color calibration charts onboard each of the landers as illuminated by ambient Martian sunlight and skylight. While this technique does not require any assumption of stability of the flight camera during its transit, it does require that assumptions be made about the color of the light with which the color charts are illuminated. Both Viking and MER rovers carried these charts. Current scientific opinion holds that the color charts and the Martian surface are illuminated in a very red light caused by large amounts of red dust in the atmosphere. The exact effect of this red dust is not currently known and is often cited as one reason why there is so much variation in color.

Prevailing theories suggest that the putative large amount of dust in the Martian sky also causes both transmitted light from the Sun and scattered light in the sky to be red. The result is a set of color imagery in which the landscape and the sky both appear red. This is the opposite of the sunset situation on Earth, in which the scattered light is blue and the directly transmitted light is red because the blue light is subject to Raleigh scattering. The theory of red Martian illumination has even been taken into account in the design of solar cells for use on Mars landers with these cells' photosensitivity peaking in the red.

The two Viking calibration schemes left a great deal of uncertainty. The color calibration algorithms tested on Earth were not guaranteed to work on Mars after such a long and difficult transit, and the color chart calibration scheme had uncertainty caused by the unknown effects of dust on the incident illumination. The unknown illumination makes it difficult to calculate the actual colors of Martian landscape and features. However, the lander color chart can be used to answer the scientific question—"How would the surface materials, sand and rocks of Mars, appear if they were illuminated by standard Earth-like conditions?"

Geologists, and possibly biologists, might be able to identify features on Mars with which they were familiar if they could be shown a coloration of the planet in normal Earth-like illumination. The onboard color charts can be used to answer this question. If colors in Martian lander images are calibrated to match the calibration chart on Earth under known illumination, then the scene surrounding that color chart would appear as on Earth under Earth illumination conditions.

One of his major findings is: *When the calibrated red panel is compared to the Earth-bound red panel, the illumination inferred on Mars is slightly shifted toward the blue. The red panel is not quite as red on Mars as is its terrestrial counterpart; however, the inferred illumination is a bluish-hue very close to white. The key finding is that the inferred illumination for the green and blue panels is enormously red.*

And "*A tenable hypothesis supporting the published calibration charts does not appear to be possible. Instead, a more likely hypothesis is that a problem exists with the red channel. Large values in the blue and green channel appear to be bleeding over into the red channel. Pixels that would have been blue or green appear to have been grayed out by the addition of red...A more robust attempt...could provide improved results. These results may show even more of the green rock colorations seen in the first Viking images.* "

It seems that there are unsolvable issues causing confusion with the calibration. Based on what has been discussed, it would seem this is why an overall reddish filter is put over all the images – they need to restore red values that somehow have been affected somewhere in the process. In addition there is the assumption that the ubiquitous red dust is constantly airborne and has an effect on all lighting on Mars.

Levin is hopeful that "*On some future date, a spacecraft may land on Mars carrying its own calibration light source of known spectral properties. Until this occurs, the illumination of Martian color calibration charts will continue to be an issue.*"

However, isn't that what lens flare artifacts provide? Light diffracts into specific and known wavelengths visible as the various hues of the rainbow. The white light of the sun contains the complete spectrum. If, however, on Mars light is modified so that more red is illuminating the environment then the study of what wavelengths might possibly be missing from lens flare artifacts could provide a lot more information as to the quality of the light. If, on the other hand, lens flare artifacts contain the complete spectrum of rainbow light, then that would be significant evidence that there is very little particulate dust in the atmosphere and the assumption of a red color calibration is not correct.

So why haven't lens flares been part of the study of color calibration? I would suggest that up until the Perseverance rover, there have been no cameras which have captured lens flare in the pictures. Can that be possible? I haven't personally examined every single image taken on Mars. But I have never come across any photographs with lens flare. Neither have I been able to find any reference to any images that people have examined. Could this be a new area of research?

For that, we have to examine the Perseverance rover.

Why are Lens Flares Only Now Showing Up?

The following link is to a paper which describes all the various technologies and capabilities of the cameras included on the Perseverance rover.

"The Mars 2020 Engineering Cameras and Microphone on the Perseverance Rover: A Next-Generation Imaging System for Mars Exploration"
J.N. Maki, et al
24 November 2020
https://link.springer.com/content/pdf/10.1007/s11214-020-00765-9.pdf

- "The Mars 2020 Perseverance rover is equipped with a next-generation engineering camera imaging system that represents an upgrade over previous Mars rover missions "

- "There are a total of 16 cameras in the Perseverance engineering imaging system"
- "The Mars 2020 Navcams and Hazcams offer three primary improvements over MER and MSL. The first improvement is an upgrade to a detector with 3-channel, red/green/blue (RGB) color capability that will enable better contextual imaging capabilities than the previous engineering cameras, which only had a black/white capability. The second improvement is that the Perseverance cameras have wider fields of view than previous versions, which improves the quality of mosaics and increases downlink efficiency. The third improvement is that the Perseverance cameras have finer pixel scale (mrad/pixel) and are able to resolve more detail than the MER/MSL cameras. All of the Navcam and Hazcam cameras for MER, MSL, and Mars 2020 were built at the Jet Propulsion Laboratory/California Institute of Technology, in Pasadena, CA."
- "All of the Perseverance engineering cameras share the same detector and camera body designs."

It is interesting to note that a figure in their document shows a color image which is a 3 channel composite but without any color calibration filter added.

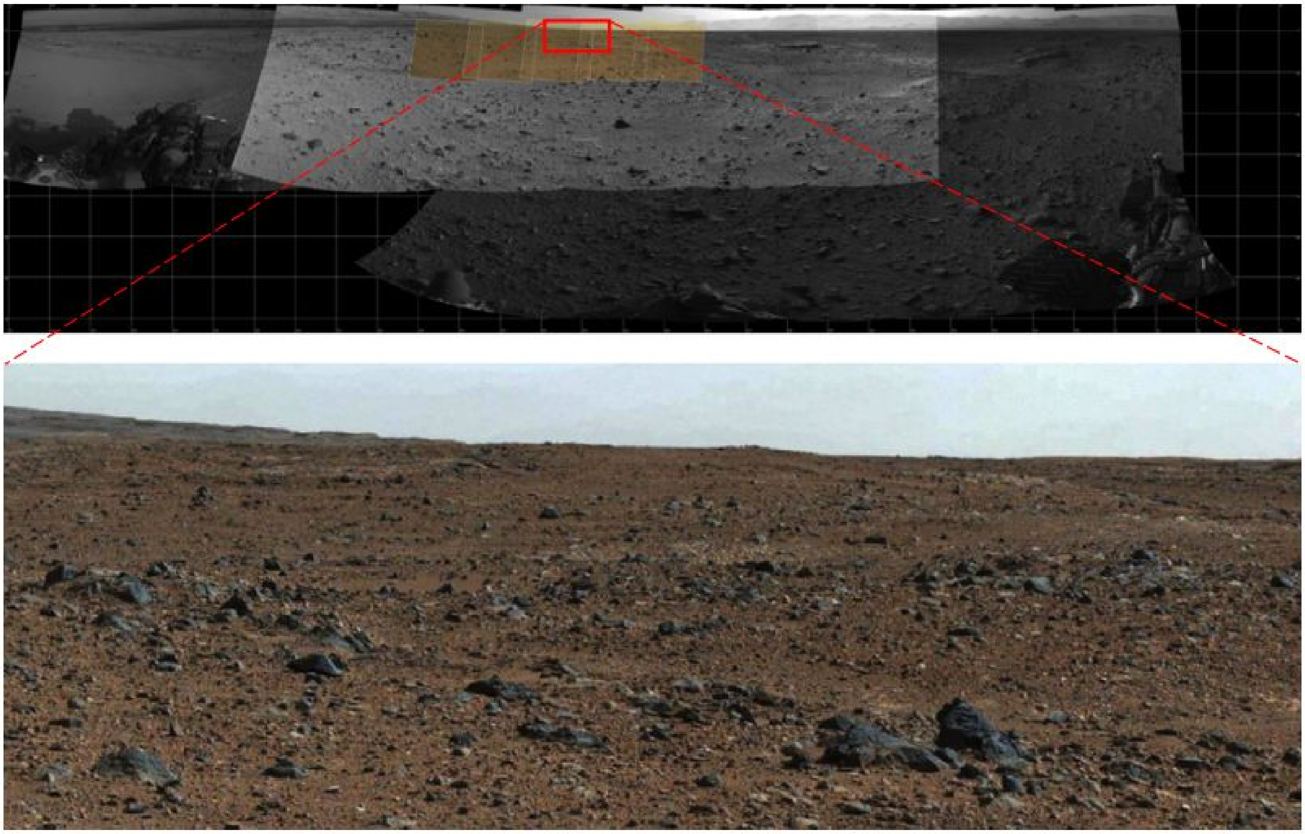


Fig. 6 Drive direction imaging with the MSL Navcams (greyscale, 0.8 milliradians/pixel) and the left Mastcam (color, ~ 0.2 mrad/pixel, inset in top image, and bottom image). The *Perseverance* Navcams have a pixel scale of ~ 0.3 mrad/pixel

- "The Front Hazcams have a sun visor mounted above the cameras to prevent sunlight from falling directly onto the lenses. This helps reduce lens flare and other scattered light artifacts "
- "Unlike the Front Hazcams, the Rear Hazcams do not have sun visors "

Is this the answer as to why no lens flares have been noticed before? Have all other cameras in previous missions included sun visors in order to make sure lens flares were not possible? It does make sense since data transfer was at a premium and lens flares usually result in images of little use. But now for whatever reason, the Rear Hazcams do not have sun visors. Lens flares are regularly occuring in photographs from those cameras. The now infamous "rainbow on Mars" photograph was from one of these cameras. It was confirmed to be a lens flare artifact.

In addition, all these cameras have wider fields of view. What does that mean? Here is a description of "wide angle lenses":

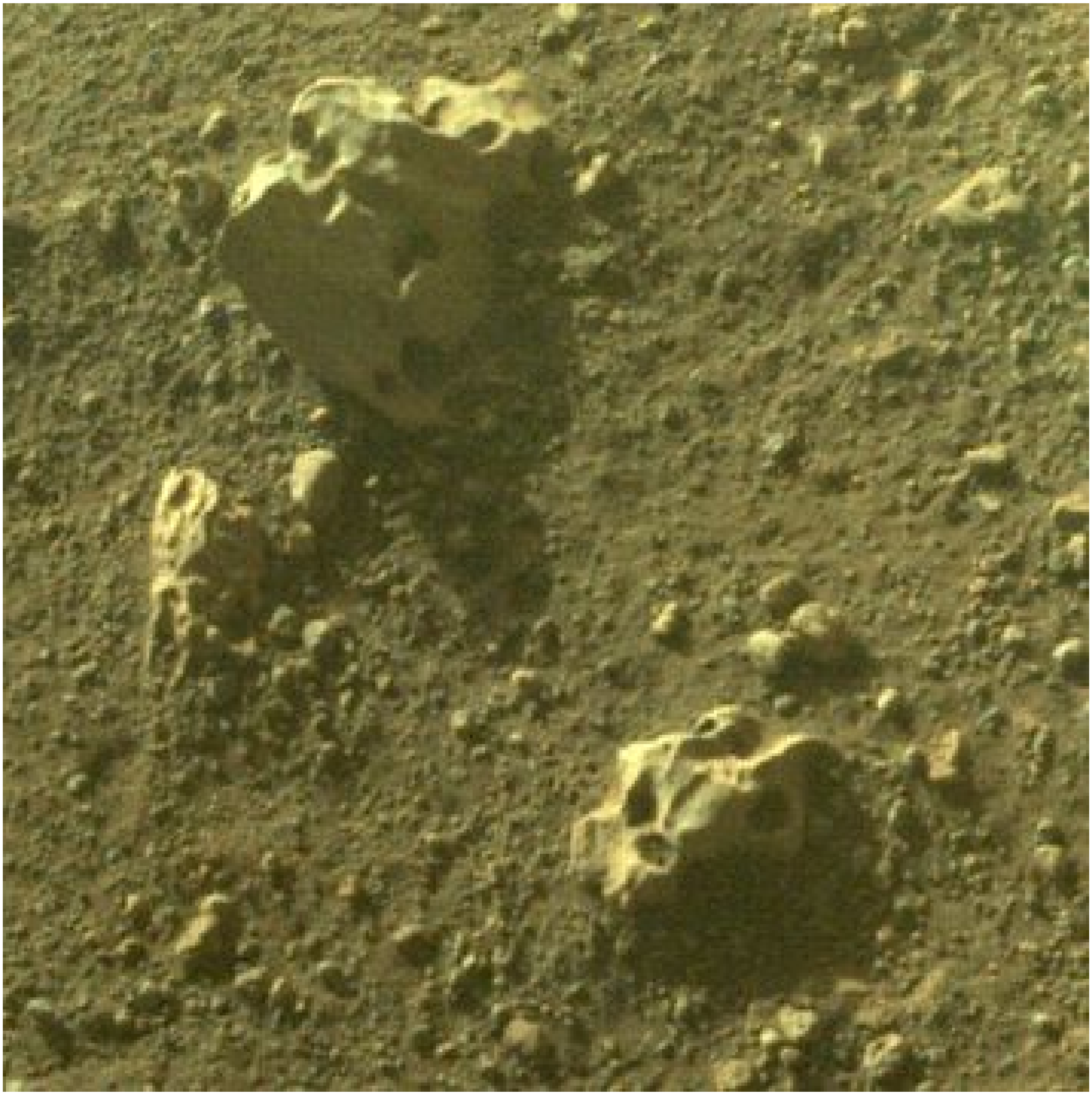
"The name says it all: wide angle lens captures images with a wide angle of view. It is a wider field of view than our eyes can see. It makes images a little unnatural, but we desire that effect in certain situations. ...The wider the angle, the greater the distortion. Wide angle lenses exaggerate the distance between the foreground and the background. It means that subjects close to the camera will be magnified, while distant objects will be compressed and diminished. With wide angle lenses, you get a deeper depth of field. The result is a pretty much sharp image throughout. Actually, the sharpness decreases towards the edges of the frame. But it is slow, gradual, and almost unnoticeable drop. It works great for some landscape images. On the other hand, you can't accentuate your subject by blurring the background...Lens flare is another common problem when using a wide angle lens. With a wide field of view, it can be hard to avoid the sun, but there is no magic solution here."

https://www.photoaspects.com/what-is-a-wide-angle-lens/

What Does This Suggest?

Based on all this information, what can this tell us about the accuracy of color photographs from Mars?

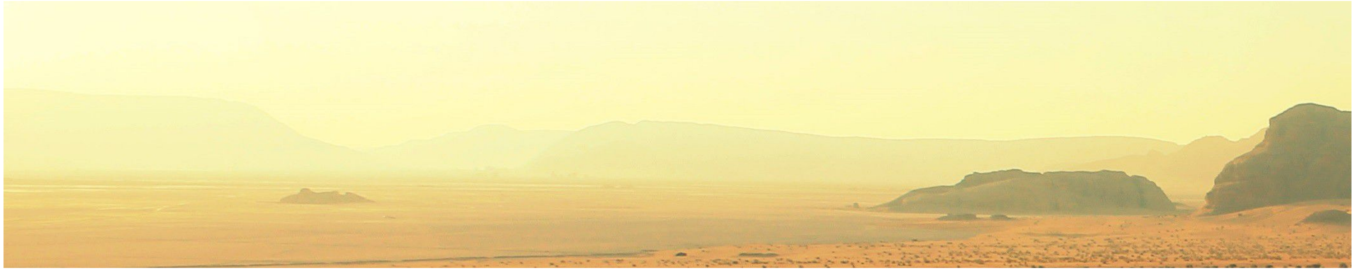
First, the question about accurate color can be separated from the question about the quality of light in the Martian environment. If unobstructed light rays are regularly causing lens flare in Mars photographs, then how much dust is really in the air? It does make sense that some level of dust is in the air which increasingly obscures objects further into the distance. However, if dust is tinting objects just a few feet in front of the camera, how is it possible that strong sunlight and hard shadows are possible? Compare with your own experience if you have ever been in a thick, pea soup like fog. If your outstretched arm is being obscured by the fog, just how much can you see in the distance? With that level of fog, hardly anything.



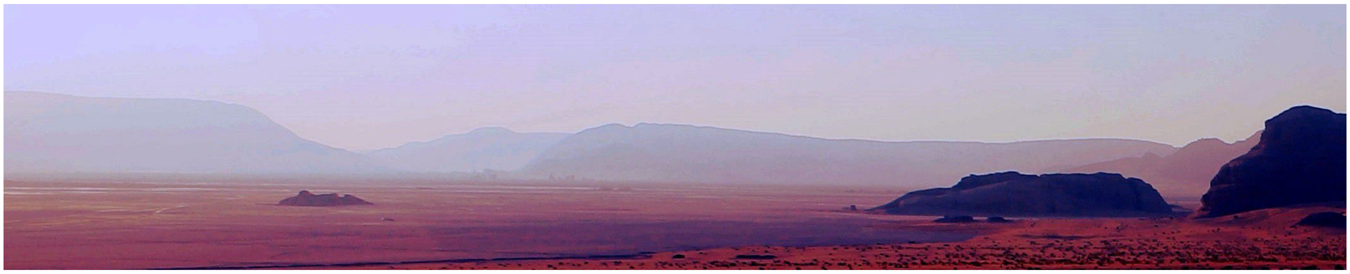
This is a portion of a photograph taken on Sol 22 and officially released. There is a very evident yellow tint supposedly from a high level of dust in the air. The rocks are only several feet from the camera. The shadows are dark and with very crisp definition. This would seem to go against an environment with that much dust evident in the atmosphere. The shadows would not be so defined because sunlight would be scattered by that level of dust and would be much more muted.

Second, it does make sense that color calibration needed to be added if, in fact, cameras were not capturing the environment correctly. However, it seems that the exact same color calibration filter is added indiscriminently over all images. It does not depend on light intensity, subject matter, or time of day. This would seem problematic as one would not do the same thing for photographs taken on Earth. The range of lighting conditions are extremely varied and must be the same on Mars.

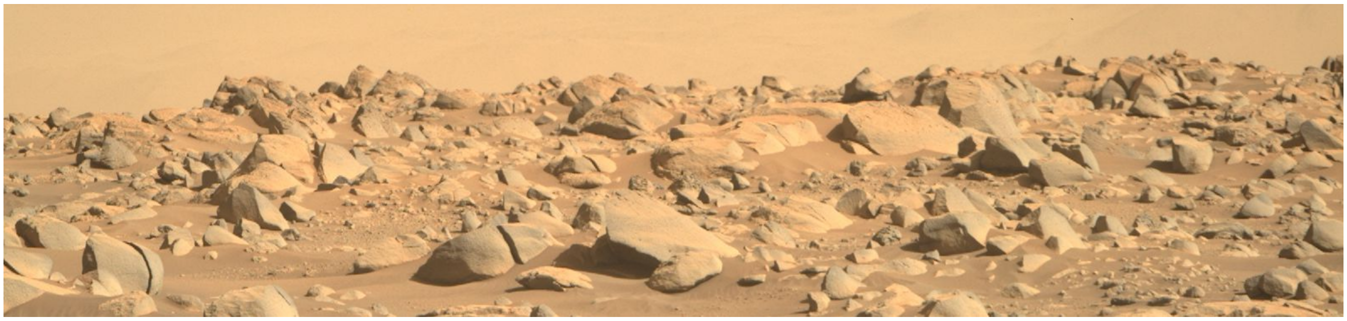
Third, there is the observation that detail exists in non-red color channels for distant objects. This should not be possible since distant objects take on the color of any particulate matter and obscure detail. I demonstrated this with a photo from Earth.



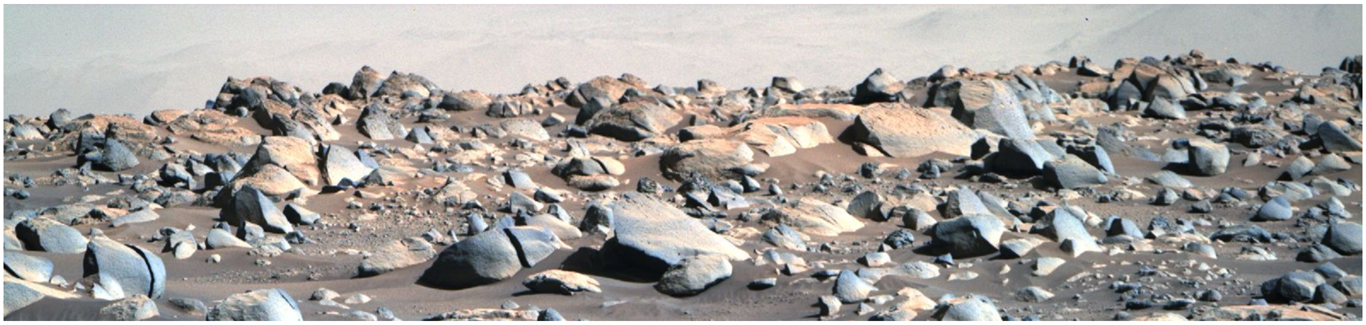
Here is a portion of a photo showing the atmospheric haze affecting distant hills. You can make out the outline of the shape of the hills but not any details about variations within. If the color channels are modified and even synchronized, here is the result.



The overall color has been shifted. However, the level of detail in the distant hills remain the same. There are no added details evident.



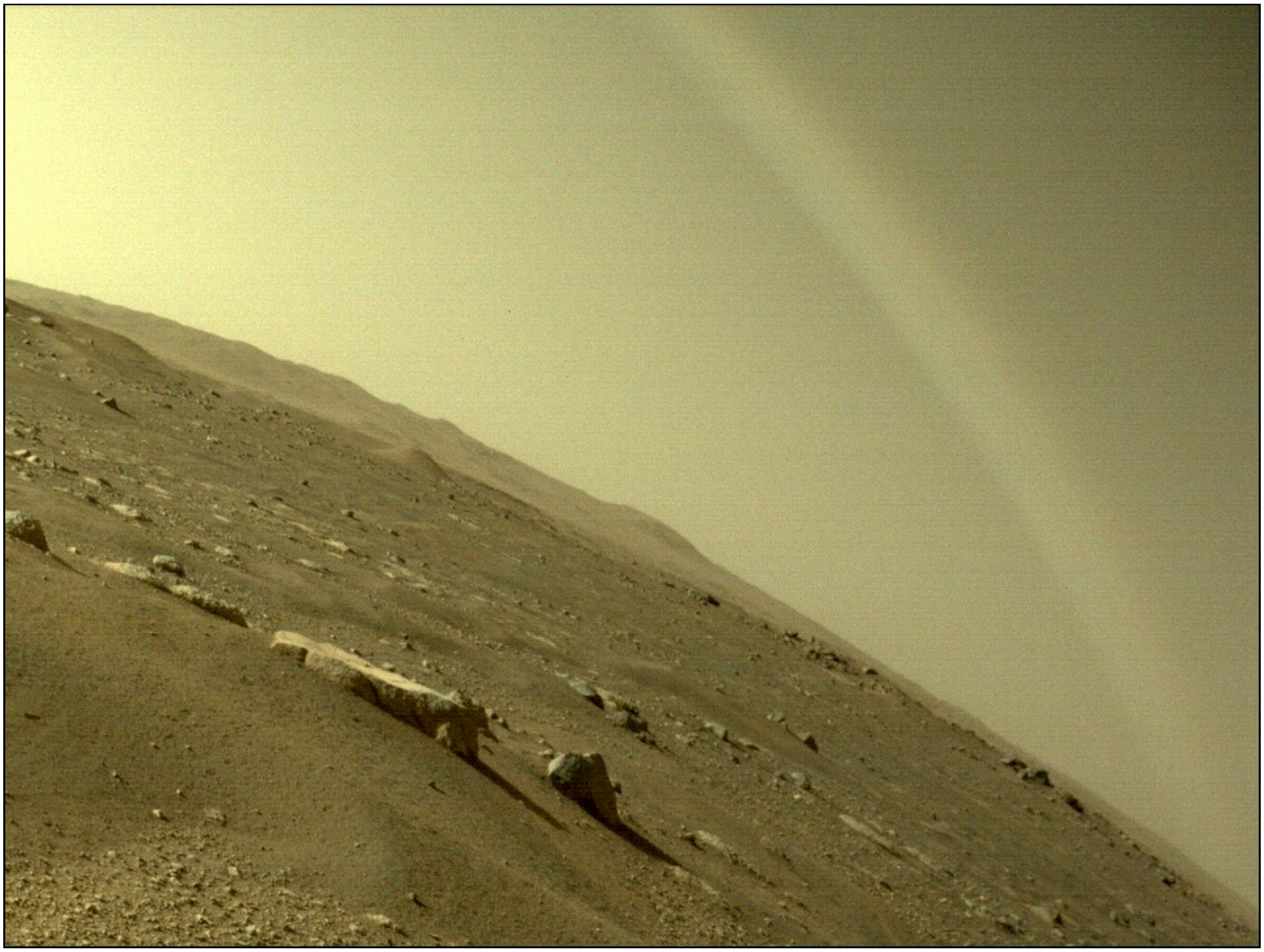
Here is a portion of an official image from Mars – Sol 22 from Perseverance. It has had color calibration added. A noticeable red tint is over the entire image. The distant hills seem to be very much affected by dust in the atmosphere. There are only shades of red evident and there is very little detail visible.



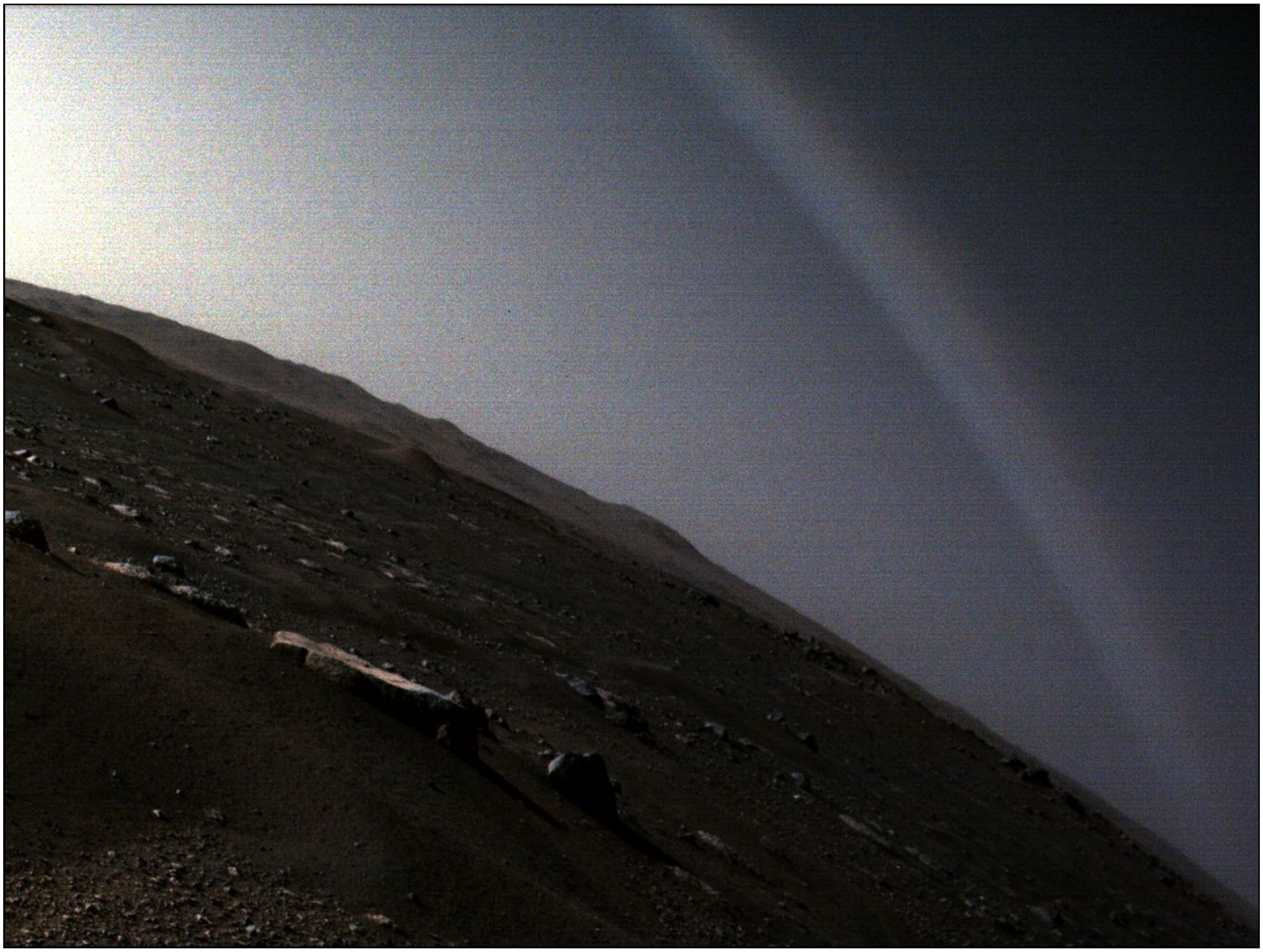
Here is that same photo but modified so that the color channels are equalized.

Notice that not only are the outlines of the distant hills more evident, but there are significant details visible for the hills themselves. There are dark and light areas visible where in the official image, there are none. This should not be possible. Distant objects take on the color of particulate matter and wash out any detail. There should not be any other detail information contained in any other color channel. This suggests that the color calibration is not accurate because the quality of light that has been captured includes the entire range of the RGB channels and not just the R channel as the official image suggests.

Lastly, the main question is just the fact that lens flares are occurring. If there is so much dust that there is a noticeable increase to the red color channel, then how is it possible that all light is not being scattered? There would be no unobstructed light rays that would be able to hit the camera lens and cause any flares. This goes against how optics behave. When all is said and done, this is the main new question that is raised and needs an answer.

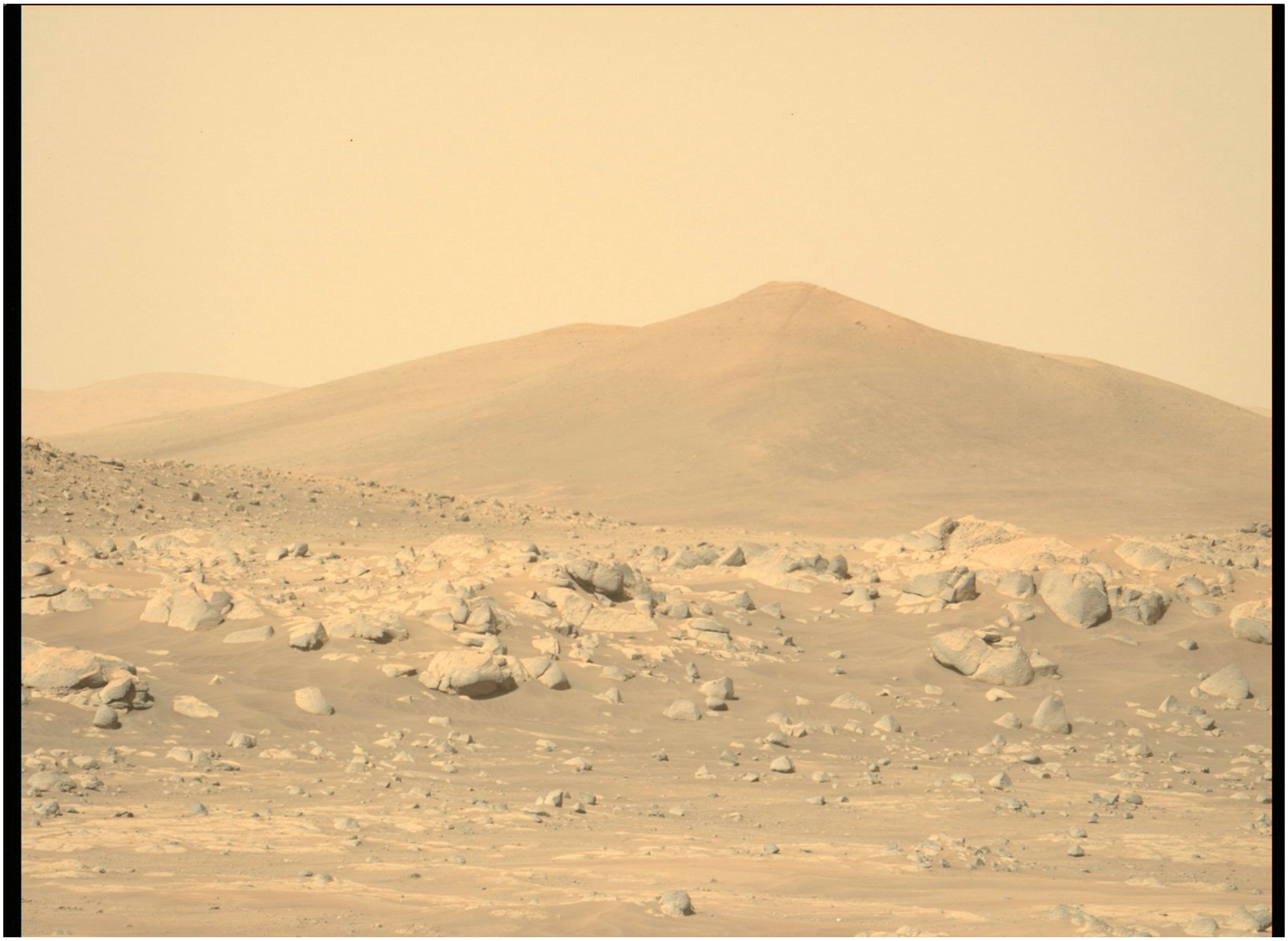


Sol 9 Perseverance official release

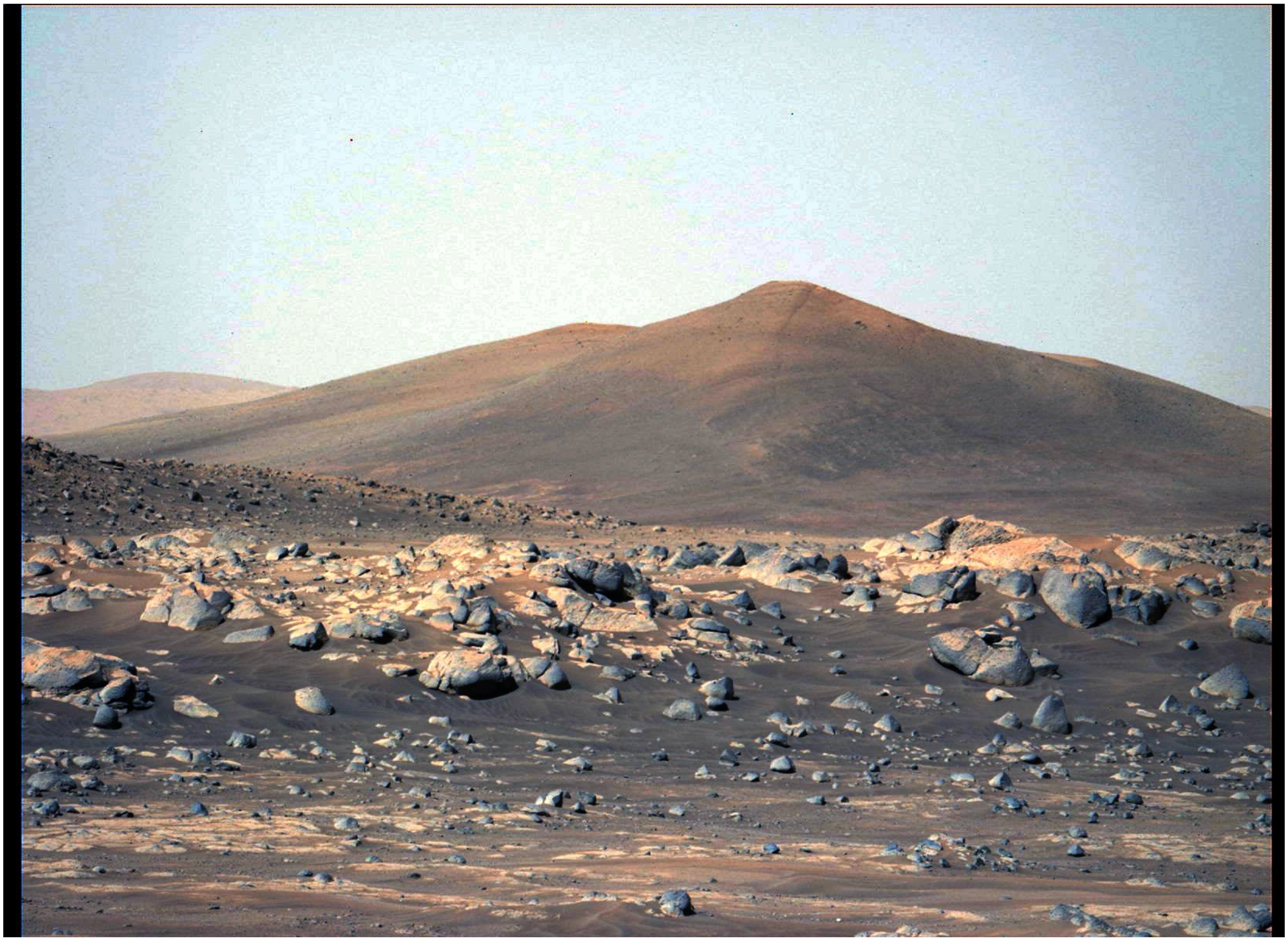


Sol 9 Perseverance color channels synchronized and light level lowered

Lowering the light level allows the lens flare to be more evident. The spectrum displayed contains the full range of rainbow hues. If, as is suggested, the light level is skewed more to red, then the light would not diffract into the complete range of hues since not all wavelengths would be included in the light. If as this complete range suggests, the light contains all wavelengths, then this suggests there is not a significant amount of dust in the atmosphere and the light is not skewed to red. This also suggests that the simple composite of the RGB data that is being captured on Mars is actually accurate and no appreciable color calibration is needed. Of course, this is only my theory. I would hope that this area could be researched fully.



Sol 59 Perseverance official release



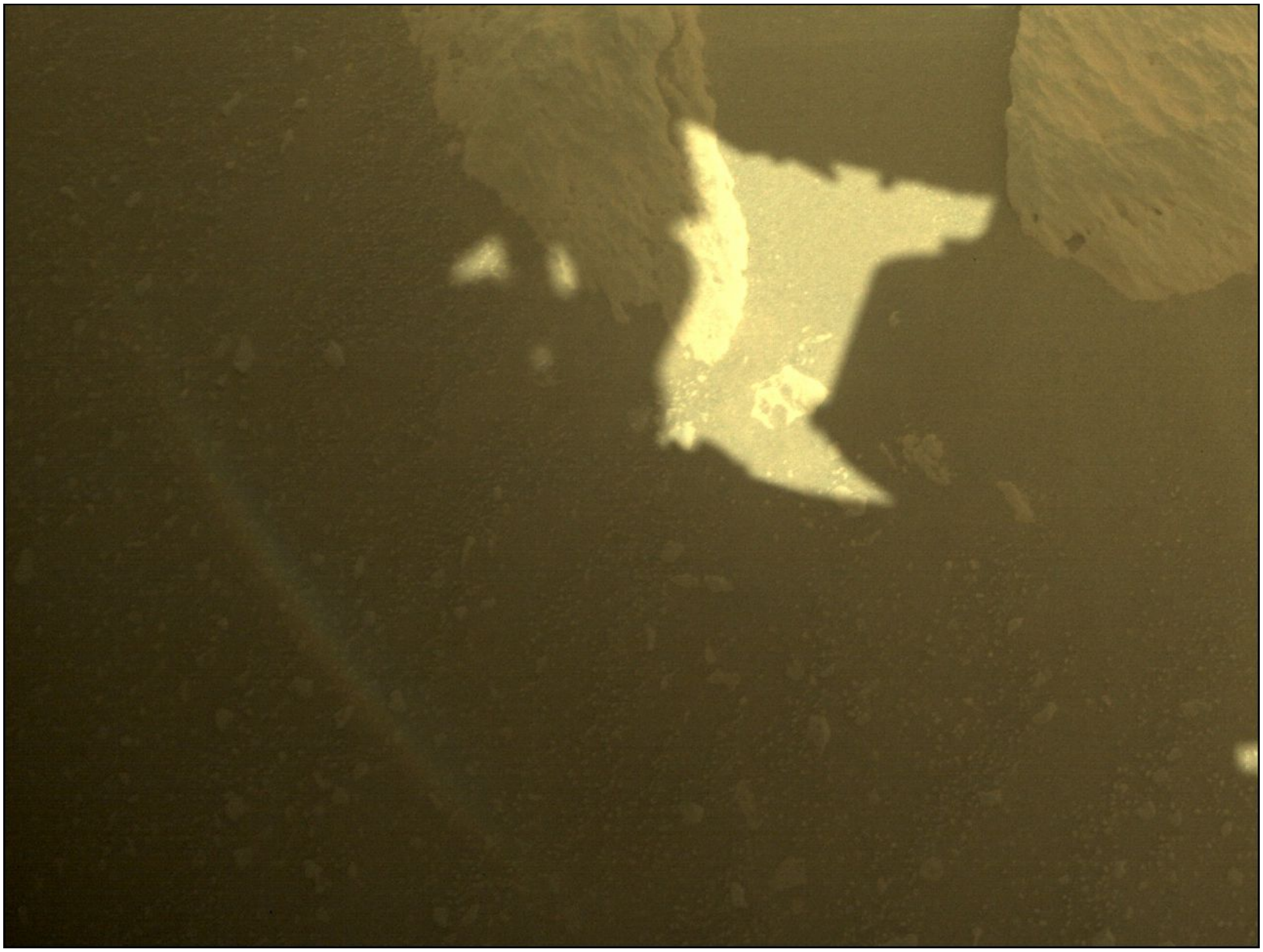
Sol 59 – color channel synchronized. This image demonstrates all the various issues that have been discussed.

Part 5: Clouds On Mars

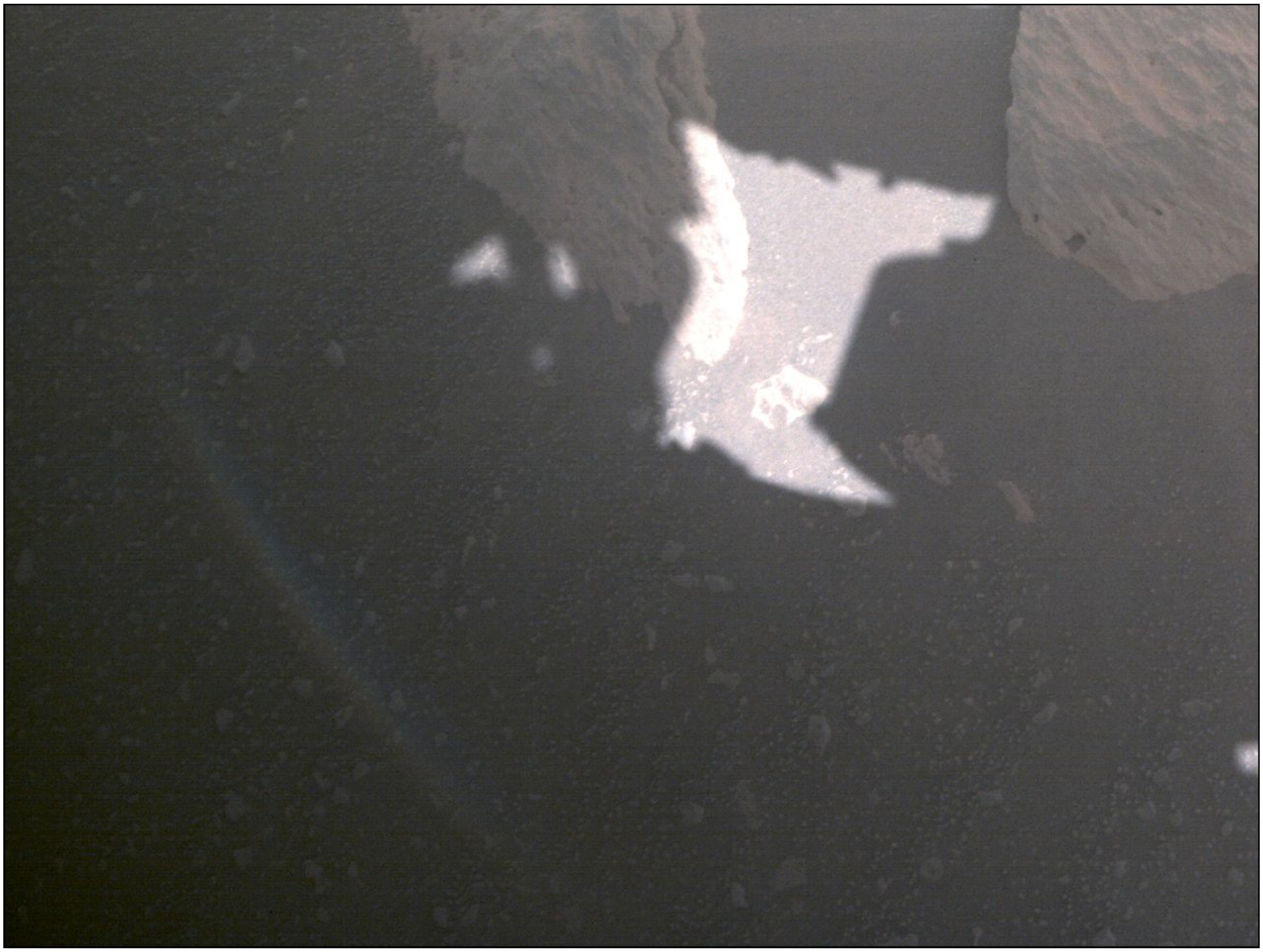
Sol 79

Is it just a regular day on Mars? It is a special day. You see, images from this day were beamed back to Earth with things that we have not seen before. Clouds. Clouds on Mars.

What kind of day was it? What were the conditions like?



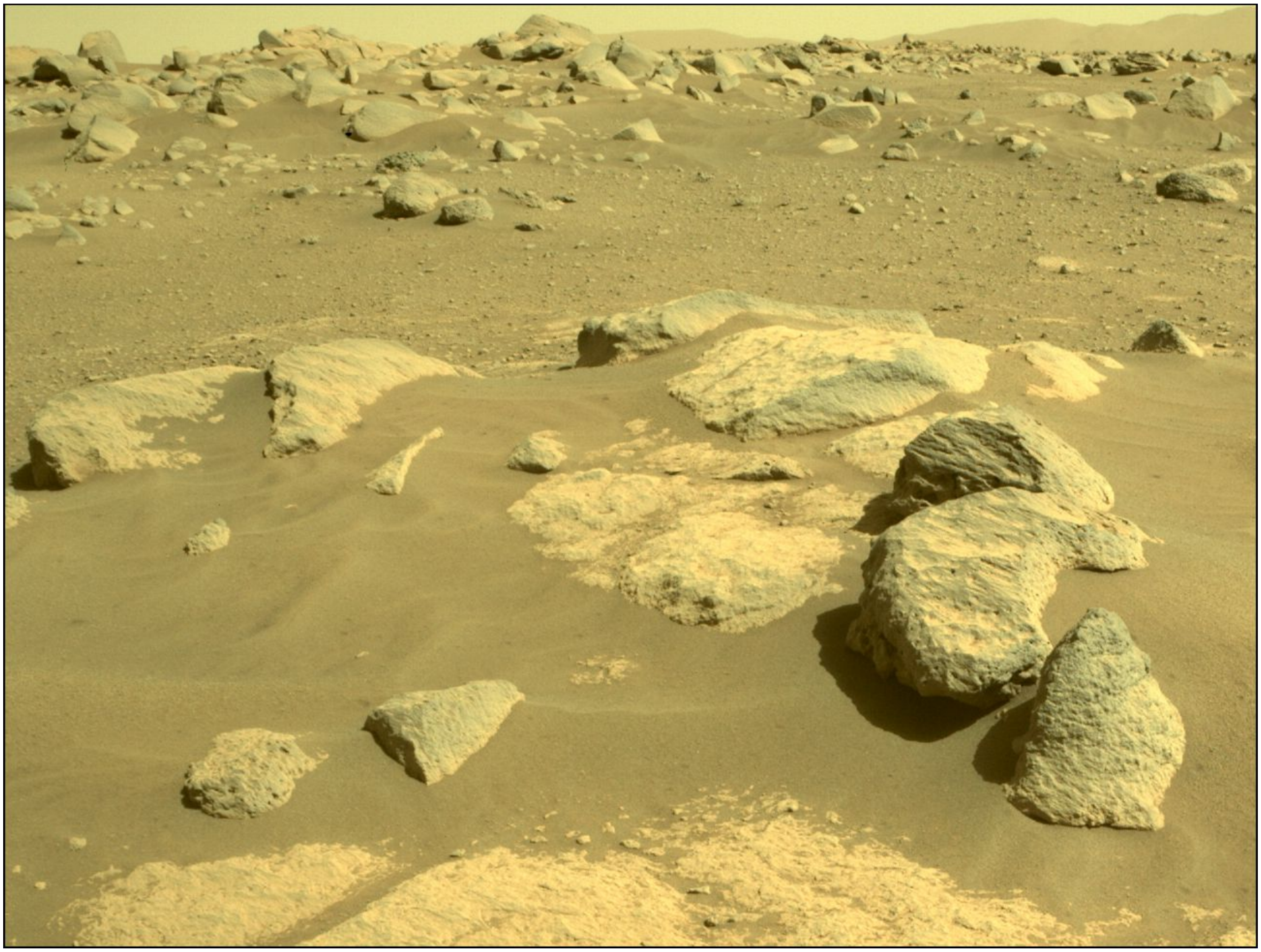
According to this photograph which is a view from underneath the rover at around 2pm, it was a very dust filled day. Everything is yellow because of the heavy amount of dust in the air. But this official NASA release is extremely misleading. How can you tell? There are two major things you can see in the image that give it away.



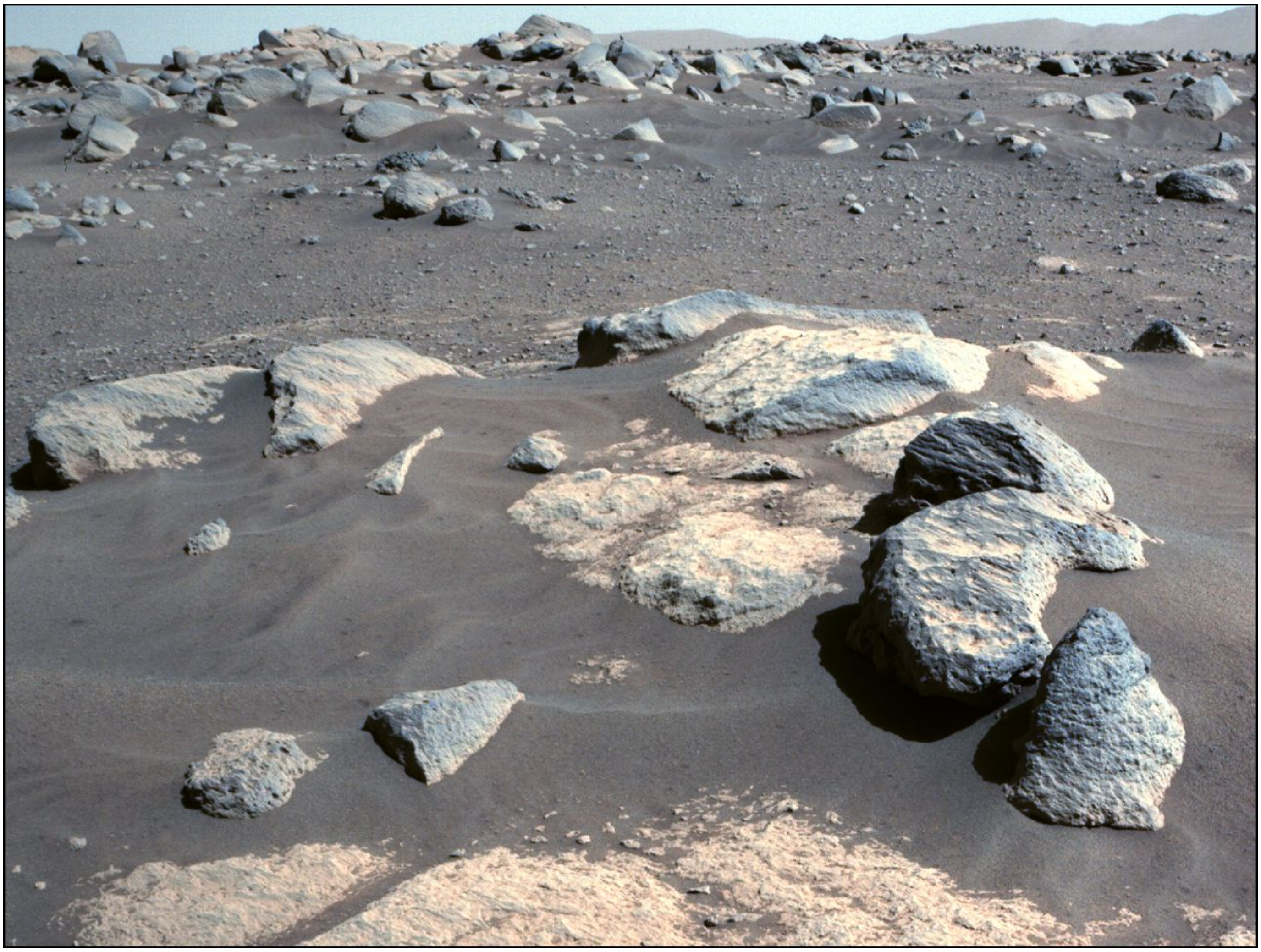
This is the same image but color corrected to return the image to the raw data that was originally beamed to Earth from Mars. You see, NASA adds their best guess of color calibration to every photograph. But originally, the raw data gets sent looking similar to the second image. And it's probably accurate because of the 2 things that are evident in this image. Look at the shadows. There is such a clear, crisp, very defined shadow line. It's like a bright sunny day would be. If there was so much dust like the first image suggests, all that dust would be blocking a lot of the sunlight and making the shadows undefined and fuzzy. Compare by looking at shadows here on Earth on a cloudy day.

Second, look at the lens flare rainbow that is in the photograph. Lens flare can not happen in cameras unless there is extremely bright light entering the lens. If there was a lot of dust in the air so that it tints everything yellow, there would be no direct rays from the sun that would be reaching the camera.

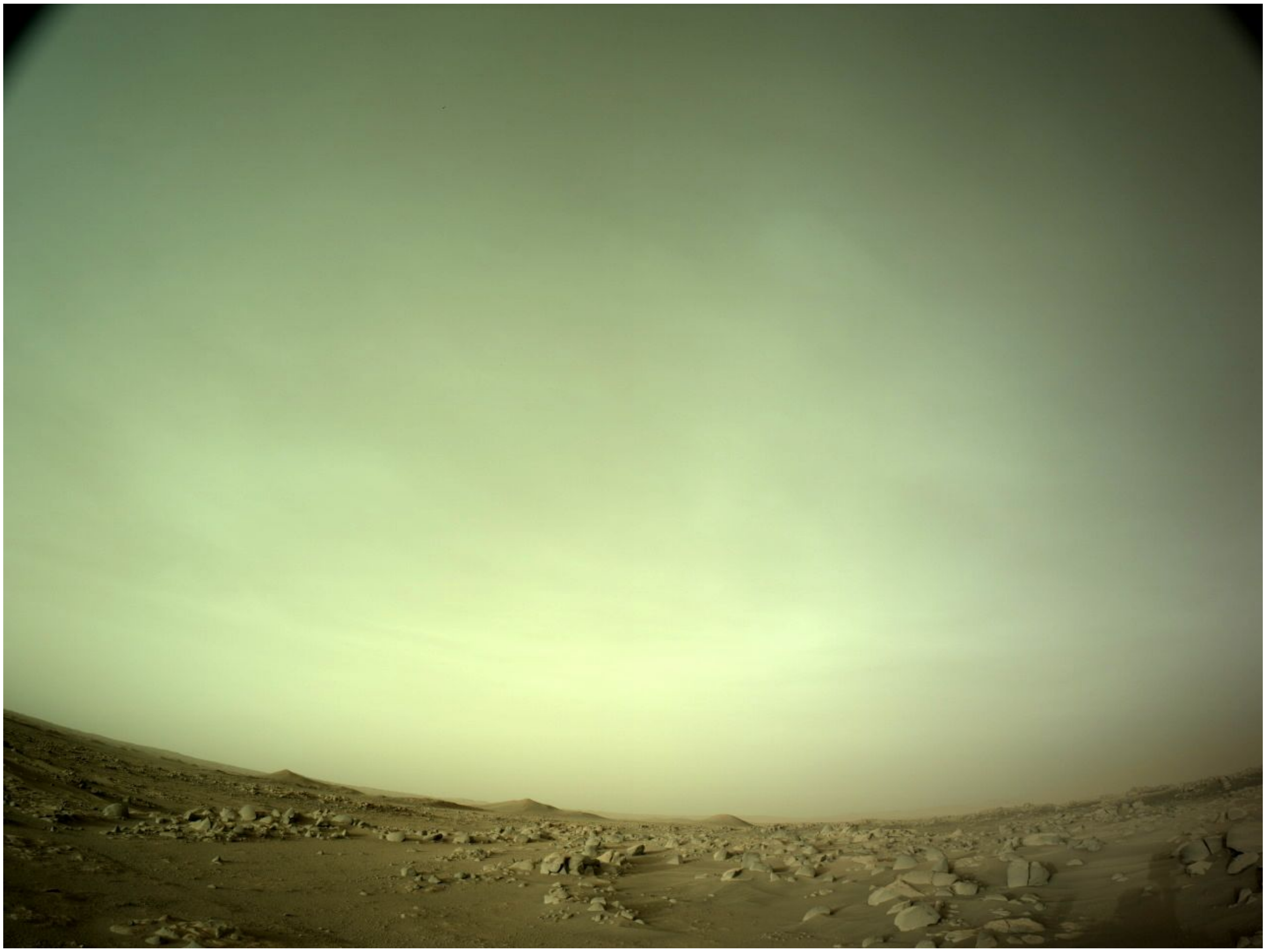
These observations show that there must not be a dusty, hazy sky but a bright, clear sunny day.



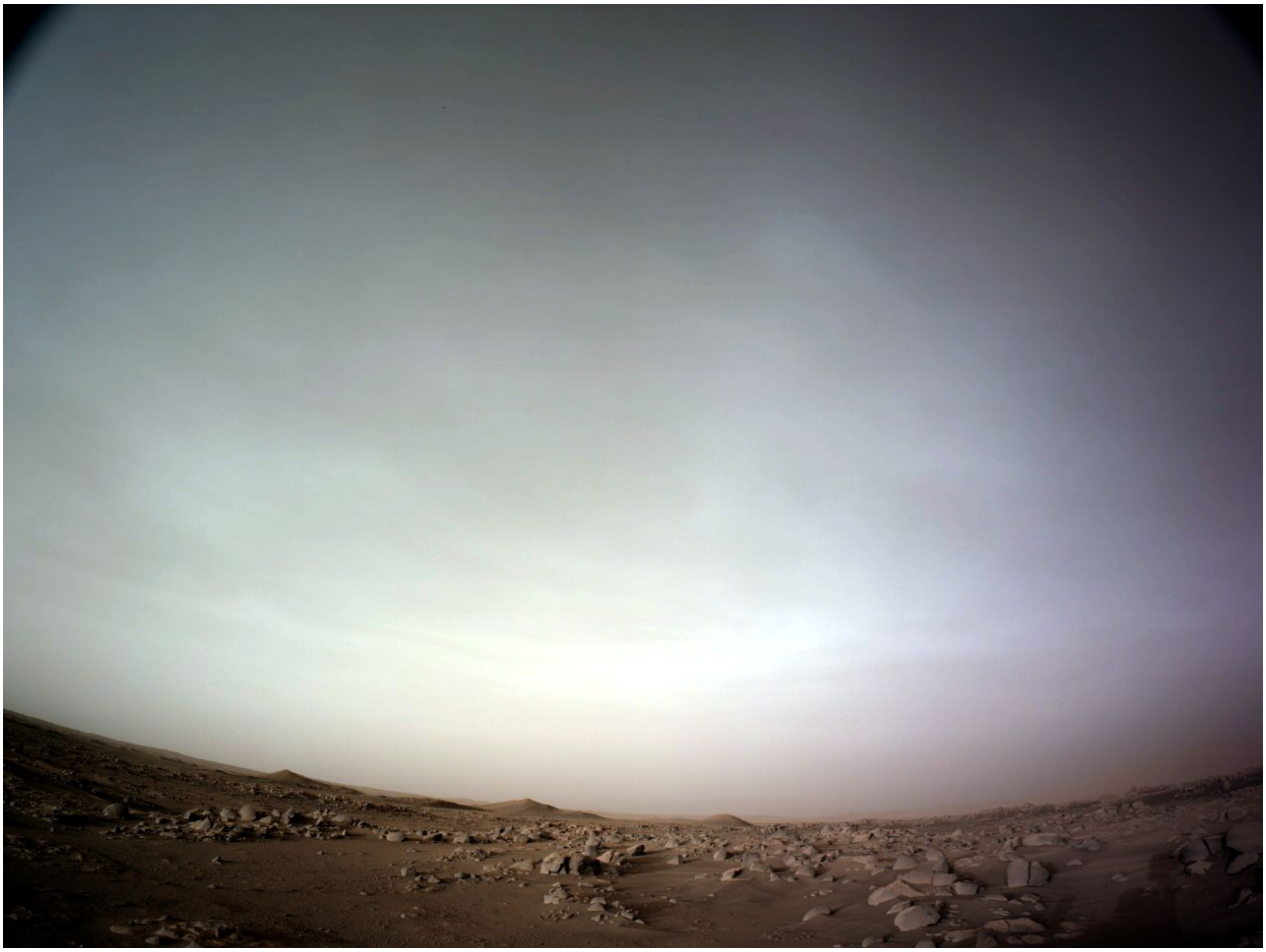
Here's another photograph taken at around 2 in the afternoon. Again, yellow and dusty.



But the raw data image that was originally sent back shows a completely different story. It's a bright, sunny day with stark, defined shadows. Notice the 2 different types of rock evident. The first is a cream colored flat rock barely covered by the sand. The second is toward the background which are a blueish-gray boulders. In the NASA official release, all the rocks are the same non-descript yellow.



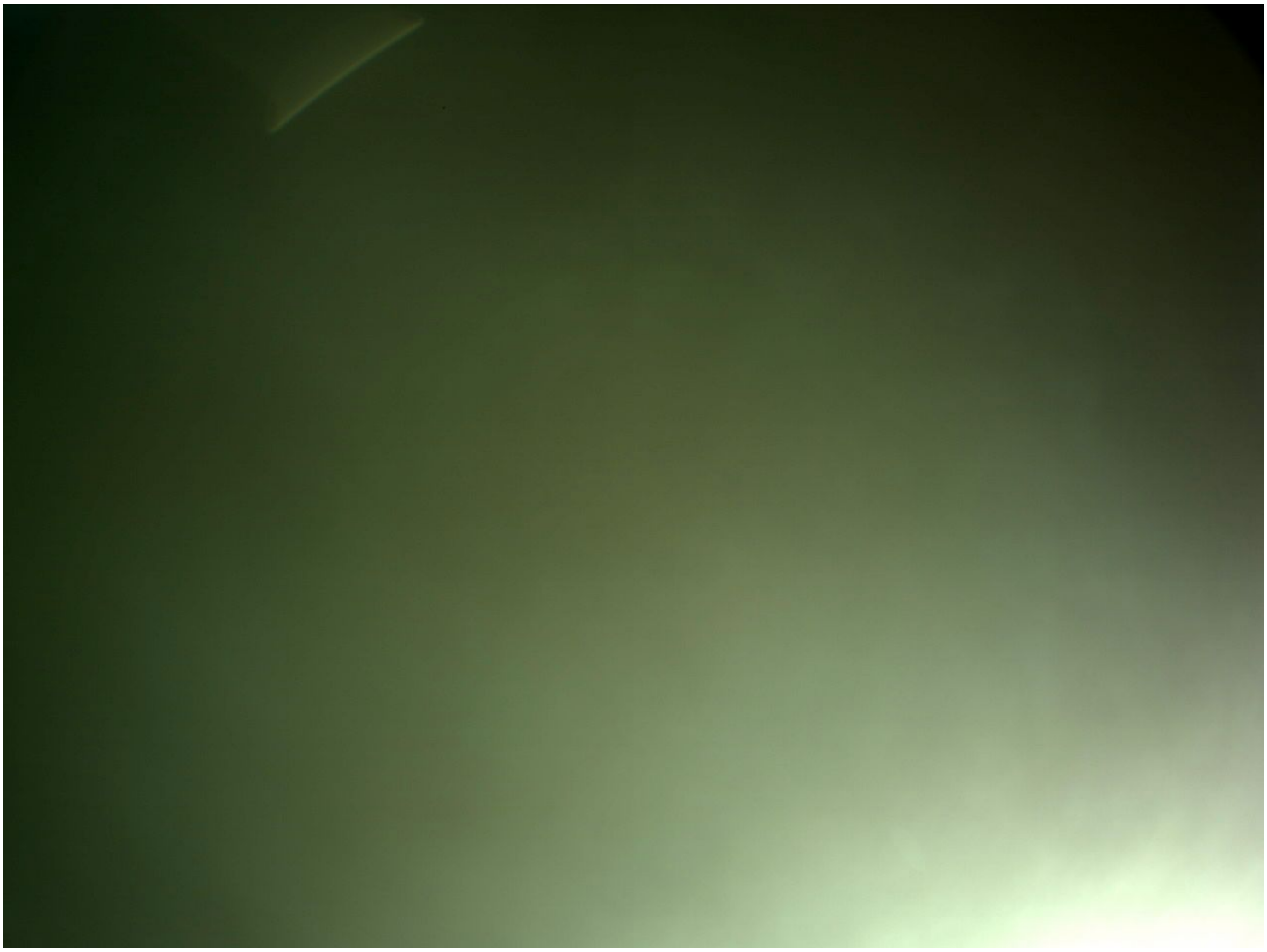
Here is the same area at 4:30 pm when the sun is setting. The shadows are getting longer. This image has a greenish tint over everything. Is it really possible that in about 2 1/2 hours everything goes from a bright yellow haze to a greenish haze?



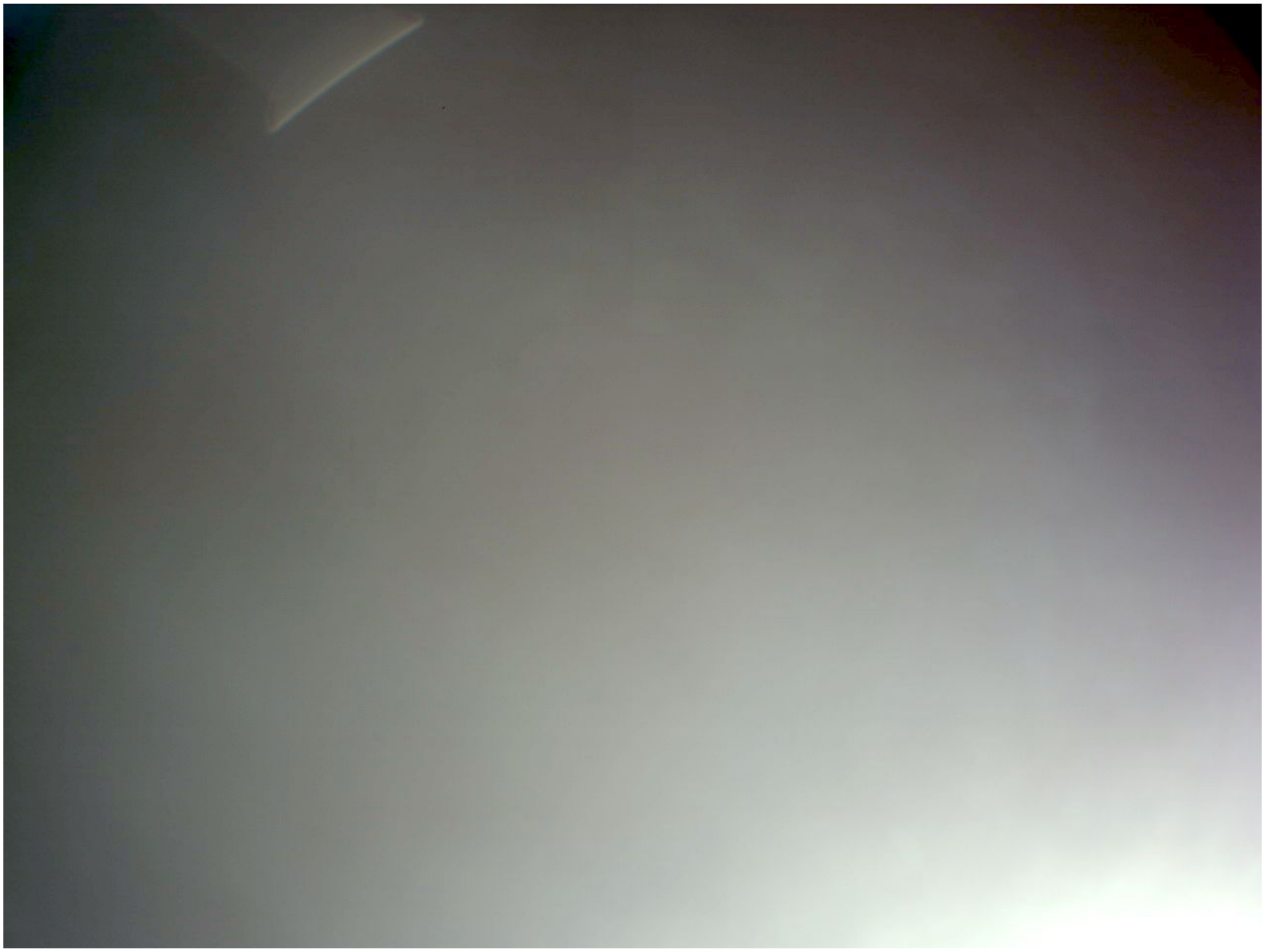
Here's the same photograph but showing the raw data image. The rocky environment is very similar in color and tone as the 2pm image but with the light losing intensity as the sun sets. The same blueish-gray rocks are evident.

The significant observation is that there are clouds in the sky! High altitude clouds with a bit of blue sky evident as well. But compare that with the official release and the sky is just a greenish mush. If there was so much dust in the air how would it even be possible to see high altitude clouds in that much distance?

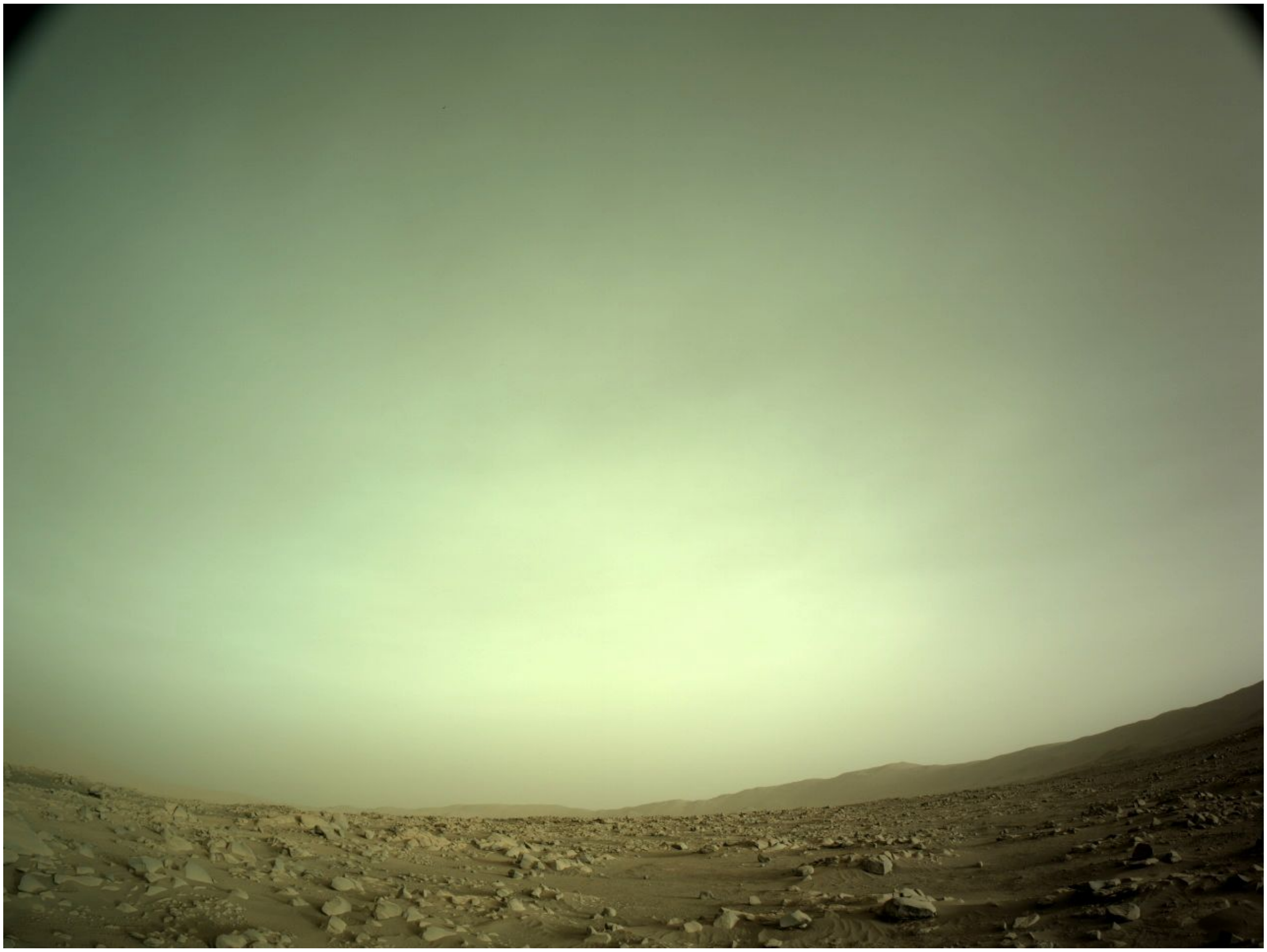
How can we tell that they are clouds and not just dust haze in the atmosphere? The next picture gives us the evidence.



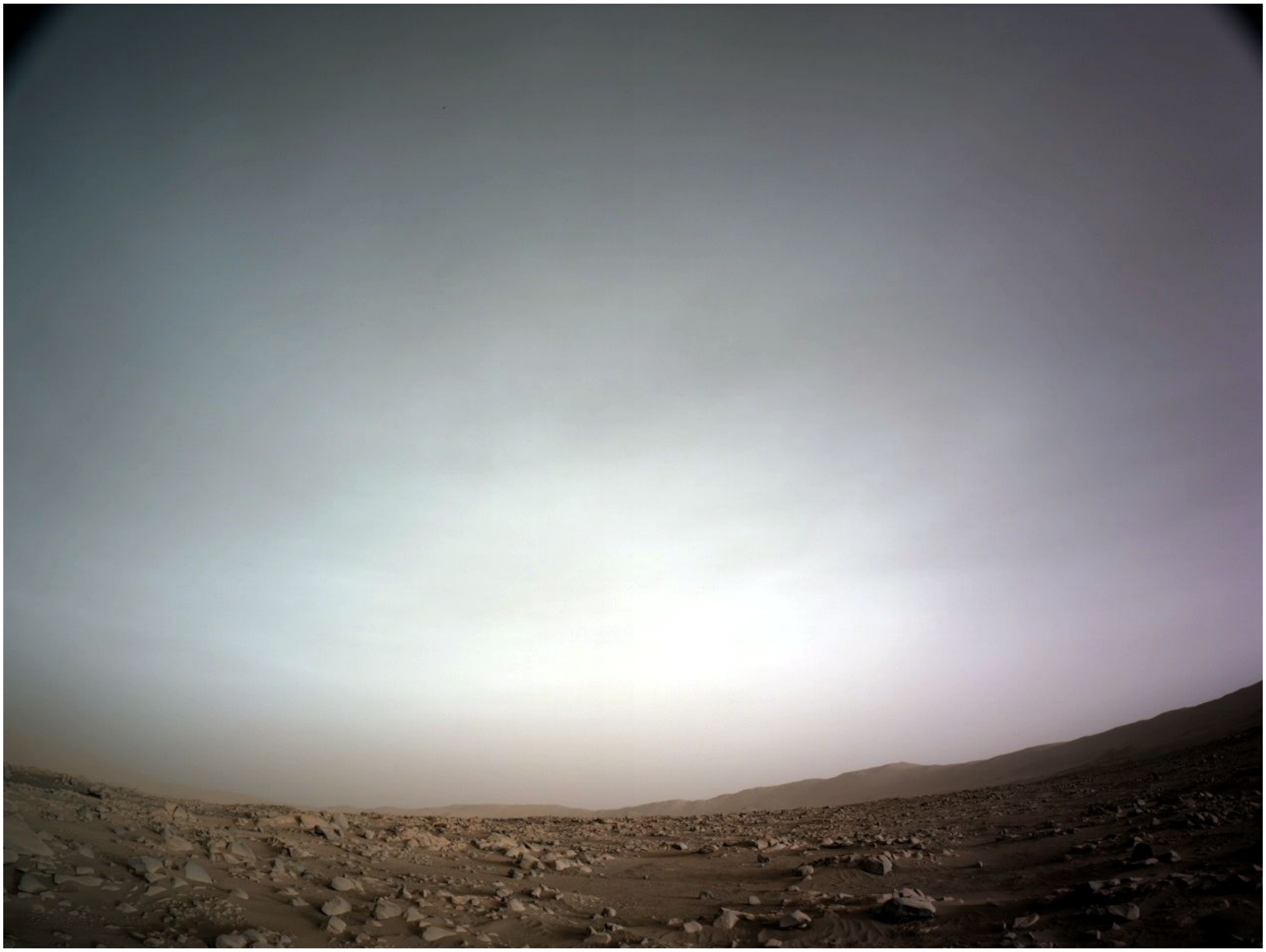
Here's another photograph of the sky at that time. A sliver of the sun is causing a lens flare artifact. Again, this can't be accurate if there is as much dust in the air as the greenish color calibration suggests.



Here is the raw data image. Unobstructed sunlight causing a lens flare which is according to the way optics behave.



Another photograph which added color calibration suggests that a greenish dust haze is in the air.



But is it really? Or are there high level clouds which are evident as the long shadows show the sun is setting?